CPE Comments and Topics

Burning the rocks

ENERGY generated from conventional power plants is becoming more, and not less, expensive. Estimates of present-day power generation costs in the U.S. are 5 mills/kWh; in 75 years costs are expected to rise to 6.5 mills/kWh. Naturally, nuclear power can only compete with conventional power if the fuel cycle costs are substantially lower (because nuclear power plants have a much higher initial cost compared with conventional plants). Only two nuclear systems at present can claim fuel costs of less than 1 mill/kWh; the unclad DRAGON-type reactor and the liquid fuel reactor.

In this country intensive work is at present carried out on the DRAGON system, but, apart from several unsuccessful attempts at Harwell, no serious study of liquid reactors has been made. Dr. Alvin Weinberg, director of the Oak Ridge National Laboratory, recently discussed the feasibility of two types of liquid fuel reactors, at a meeting of the British Nuclear Energy Conference sponsored by the Institution of Chemical Engineers. He pointed out that there are two important considerations which must be borne in mind when discussing the economics of breeder-reactors. Firstly, the expense of extracting uranium and thorium from granite rocks and, secondly, how to solve the high cost of fuel recycle. It was shown that thorium has already been extracted from granite containing 24 p.p.m. thorium by a process that costs about $140/lb., thus there is sufficient thorium available in rocks to last for thousands of years. The fuel recycle problem has been solved by making the system a homogeneous chemical reactor (unlike the usual heterogeneous reactors, which are built apart from the fuel element).

Two types of liquid fuel reactors were reviewed. The first type, aqueous homogeneous reactor (of which two prototypes are already in existence), consists of a stainless-steel sphere through which a fissile solution such as uranyl sulphate in water is circulating at 1,000 p.s.i. The core is surrounded by a blanket of heavy water. The system operates at two pressures, one at 1,000 p.s.i. and the other at atmosperic pressure, which are separated by a let-down valve.

Due to several significant disadvantages of the aqueous homogeneous reactor, *i.e.* high pressure, low temperature and lack of a liquid blanket, molten salt reactors were developed. The choice of molten fluoride rather than chloride was made because the free energy of formation of UF_4 and ThF_4 is higher than that of nickel, molybdenum and iron fluorides; hence these molten fluorides should not attack nickel-based alloys. Unlike the A.H.R. system, the higher the temperature the more soluble the uranium; hence

these reactors can be operated at much higher temperatures. Although thermodynamically the molten fluorides are compatible with common materials of construction, it has been found that chromium-containing alloys can lose their chromium to the salts by diffusion and, as a result, Oak Ridge metallurgists developed a new alloy, INOR/8, whose main constituents are nickel 67%, molybdenum 15 to 18%, chromium 6 to 8% and iron 5%. This was found quite satisfactory as a material of construction.

Finally, Dr. Weinberg raised the question: are liquid reactors practical? It could quite well be claimed that the A.H.R. represents the final rationalisation of pressurised water technology and the M.S.R. of sodium-cooled reactor technology. The trend in reactor technology today is definitely towards dirty systems because of the great improvements in neutron economy. Hence liquid reactors can represent the first attempts to learn how far the dirty system can be utilised. Naturally, safety considerations are of utmost importance and the Oak Ridge team has consistently placed the most rigorous demands on a satisfactory secondary containment system. Although many practical difficulties must still be overcome in perfecting liquid fuel reactors, Dr. Weinburg believes that the energy sources for such reactors, *i.e.* the rocks, represent unlimited supplies for mankind, and this is at least as important as the achievement of thermo-nuclear energy (which has received far more publicity with fewer positive results). It is because of these high hopes that Oak Ridge feels justified in carrying out considerable experimentation on the liquid reactor system.

Status symbol—the slide rule

THAT the Institution of Chemical Engineers is a swiftly growing professional body was once again shown at the annual general meeting held on April 25 at the Park Lane Hotel, London. Total membership for all grades of the Institution at the end of 1960 was 5,302, representing an increase of 430 over the previous year. One of the most important tasks in which the Institution is at present engaged is, quite naturally, education. The annual report points out that, whereas in 1949 only 99 chemical engineers qualified at British universities and technical colleges, this number had risen to 498 in 1959. This country therefore has the third largest output of chemical engineers in the world after the Soviet Union and the U.S. Nevertheless, this output has not risen at the expected rate. In 1956 it was estimated that, by 1959, 727 chemical engineers would qualify in this country as compared with the actual figure of 498. It could therefore well be that estimates for chemical

engineers who will qualify in 1962 and 1965 are also too high (these were given as 875 and 1,052 respectively).

At the annual dinner the outgoing president, Mr. W. K. Hutchison, remarked that in our society official recognition of the importance of engineering to the national well-being has done little to eradicate the social perception of an engineer as a man of few words—those usually rude—and less culture, his status symbol being a slide rule. 'Are not we, the engineers, to blame for this?' asked Mr. Hutchison. 'The government obtains the opinion of organised industry and trade unions before making up its mind about subjects as diverse as disarmament and the opening of public houses, yet the professional and managerial classes have not yet made up their minds about the metric system.'

The significant lack of status for engineers (including, of course, chemical engineers) seems to bear little relation to their dire shortage at present. The very fact that an engineer can be anything in the public eye from a professor of a university department of engineering to a member of the A.E.U. is some evidence of the current confusion. This ignorance by the public might well be caused by the fragmentation of the various branches of engineering into different professional bodies, so that it becomes increasingly difficult for a member of any one engineering institution to gauge the breadth of the whole profession. Surely there is some need for an overall 'Engineering Council' akin perhaps to the British Medical Council, whose sole task would be to safeguard the professional status of engineers and to 'put over' to the public the right image of an engineer, whether he be chemical, mechanical, electrical or civil. This, in the long run, is the only way by which the dignity and status of the engineer in our society can be raised and, without the right 'status', young people will never be attracted in sufficient numbers to enter this profession.

Chemonuclear reactors

PROCESSES that involve radiation are by now well known in every sphere of industry; medicine, food processing and plastics are but a few of the applications where irradiation has proved useful. However, the sources of all such irradiations are particle accelerators and radioisotopes which make use only of beta and gamma rays whose energy never exceeds 6% of the total fission energy. It would be far more efficient, therefore, to tap the energy of recoiling fission fragments by passing a process stream through a nuclear reactor whose core contains unclad fission uranium (called chemonuclear reactors). However, many problems are still involved in the safe operation of chemonuclear reactors.

Already four years ago Harteck and Dondes, of the Rensselaer Polytechnic Institute, New York, obtained yields of 5 to 15% nitrogen dioxide by exposing compressed air to recoiling fission. This can then be converted into nitric acid (see CPE, 1960, **41**, 168). Recently, Harteck and Dondes described a new fuel concept for a fixed-fuel matrix before the Congres-

sional Joint Committee on Atomic Energy. In this the fuel is stationary in the coolant stream passing through the core. The fuel matrix is made of silica glass fibres, 1/10,000 in. diam., impregnated with U_3O_8. It has been estimated that about 46 to 80% of the fission-fragment recoil energy could be used effectively in the reaction with process gas. The application of this concept can also be extended to power reactors. By suitably increasing the diameter of the fibres the fission products would be unable to escape and their energy converted into heat.

A property of glass fibres, according to Harteck and Dondes, is that they act as their own filter for radioactive contaminants and are capable of self-cleaning. In addition, it was found much cheaper to reprocess glass-fibre nuclear fuel elements after use (reprocessing represents a large proportion of nuclear fuel costs). A most remarkable achievement in this field has been the incorporation of plutonium into glass fibres. Plutonium was found to be tightly held in glass and in this form did not spread contamination. It can therefore be handled without some of the rigorous requirements at present specified.

This work is a good example of the chemistry of the future. Once nuclear energy is harnessed to chemical processing the whole face of the chemical industry will change entirely. We are at present standing on the threshold of this era.

Non-ferrous metals production

THE year 1960 was a record year for European non-ferrous metals production and consumption as well as for imports. This was recently revealed in a report by the O.E.E.C. Non-Ferrous Metals Committee which stated that the upward trend of activity continued for the first nine months of the year, but it was felt that this might weaken somewhat towards the end of the year and early 1961 due to the limited amount of capacity and credit restrictions.

Progress in processing industries, particularly for aluminium and copper, has been quite spectacular according to the report, and the production of aluminium and copper semis and castings is reported in some countries to be 25 to 30% up on the first half of 1959. Although some new capacity has come with service, deliveries are still abnormally slow in some cases. In the zinc-processing industry, the greatest expansion was made in die-casting and brass products. According to the exports, zinc and aluminium die-castings are now meeting with more and more competition from plastics. Demand for lead products remained stable but demand for nickel steel and anodes was stimulated by the insistence on better finishing.

The non-ferrous metals industry in the O.E.E.C. countries has been in continual expansion since 1950 to a much more marked degree than in any other areas of the Western world. Both production and consumption rose by over 50% and net imports more than doubled, thus increasing considerably the overall dependence of the area on raw materials supplied from outside.

River pollution—an insoluble problem?

ALTHOUGH in specific cases, *i.e.* detergents, pollution of rivers by industrial effluents seems to have been satisfactorily halted (see 'The Luton Experiment' by B. A. Southgate and G. E. Eden, CPE, 1961, **42**, 5), the bulk of effluents in highly industrialised areas still present special difficulties to both the Health Authorities and the River Boards. Dr. L. Klein, presenting a paper to the Scottish Branch of the Institute of Sewage Purification, gave some examples of the concentration and quantity of trade effluents that are discharged into relatively small rivers.

The River Irwell, for example, is a mere 38 miles in length; pollution begins at the top of the river where a firm of textile printers take in most of the river and its feeders and discharge it as trade effluent. Altogether the river daily receives 42 million gal. of sewage works effluents and 45 million gal. of trade effluents (representing discharges from nearly 90 sewage works and 200 industrial works). Since the total water content of the river is 121 million gal./day it is evident that this consists largely of sewage and trade effluents with little clean dilution water. This is therefore a very hard-worked river with little chance of improvement by self-purification. It has a biochemical oxygen demand of 80 to 100 p.p.m., which increases after a dry spell to a value of 100 to 400 p.p.m.

The problem is further complicated by the fact that there are certain industrial wastes for which at present no suitable methods of further treatment are available. Examples of such wastes are gas liquor, kier liquors from paper pulp mills, kier liquors from cotton mills, calico printing wastes and tannery wastes. Although under a 1951 Act of Parliament it is an offence to discharge to a river anything 'noxious, poisonous or polluting' the law nevertheless permits such a discharge if all reasonable practicable means of purification are being used—and if there is nowhere for the effluent to go other than the river.

As a possible means of improving such rivers Dr. Klein suggested treatment of river water. This was first put forward by H. Wilson in 1954, who mentioned the following methods by which this can be carried out:

(1) The construction of shallow artificial impounding reservoirs or lakes where the stream could recover naturally during the long storage period.
(2) The construction of aeration plants to increase the amount of dissolved oxygen in the river.

Impounding lakes have been used with moderate success in the watershed of the river Rhur in Germany; however, the expense of constructing such lakes and the very large areas of land required would probably rule out their use in this country. The proposal to use aeration plants for rivers is more practical and it has been shown in the U.S.A. that the Flambeau River, polluted by sulphite cellulose waste liquors, has improved considerably when aerated. Experiments on the turbine aeration of river waters have also been reported from Germany and the U.S.A. Swedish authorities recently started a large-scale experiment treating lakes with compressed air introduced through a perforated plastic hose. The dissolved oxygen in one case increased, in less than three weeks, from 0 to 57% saturation.

Design of water-tube boilers

STEAM-RAISING has always been more of an empirical art than a fundamental science. In order to design steam boilers on scientific principles, basic data of a fundamental nature must be known to the designer. Recent work carried out at Cambridge along these lines is therefore particularly useful. A research project, sponsored by the Water-tube Boilermakers Association on flow conditions and pressure drop of steam-water mixtures in tubes was recently presented as a paper to the Institution of Mechanical Engineers by R. W. Haywood and others.

The primary object of the project was to establish experimental data relating to the flow conditions and pressure drop of high-pressure steam-water mixtures flowing along heated and unheated pipes in both horizontal and vertical pipes. Simple boiler circulation theory is based upon the assumption that the steam-water mixture moves as a homogeneous fluid, but hitherto there has been little existing data on the relative velocities between the steam and water phases, a phenomenon that is known to exist under actual flow conditions in a boiler circuit. The paper analysed experimental results obtained from measurements of the absorption of gamma rays (from a cobalt-60 source) in their passage through the two-phase mixture. These results enabled calculations of the apparent density of the fluid mixture to be made and hence the respective velocities of the two phases at that point. Preliminary tests involving scans along a number of chords of the tube cross-section showed that the density distribution of the fluid was different with horizontal and vertical pipes.

Another part of the paper presented an analysis of the pressure-drop measurements made on 1-in. and $1\frac{1}{2}$-in.-bore pipes in the vertical and horizontal positions, with particular attention to the frictional pressure drops in the horizontal pipes. The authors stated in their conclusions that the experimental pressure drops at 2,100 p.s.i. were close to the value predicted by homogeneous theory for both horizontal and vertical pipes. For horizontal pipes at lower pressures, homogeneous theory gave a closer prediction of the pressure drop for heated than unheated pipes, owing to the opposing effects of two-phase flow conditions on the frictional and acceleration pressure drops in heated pipes. For vertical pipes at the lower pressures, the experimental pressure drops were significantly greater than the values predicted by homogeneous theory. The gravitational contribution to the total pressure drop was dominant.

Only through the use of information such as this can the designer undertake economic proportioning of the circulating circuits of such boilers.

Cost engineering

IN this age of increasing numbers of specialised technical associations, it becomes more and more difficult for the scientist, technologist or engineer to keep abreast of developments within or slightly outside his own field. The *raison d'être* of many of these technical associations is frankly quite puzzling, since they contribute very little to the general state of learning and often have no homogeneous membership. Sometimes, however, there is a vital need for a particular type of technical society and, as soon as a nucleus membership is formed, it grows very rapidly indeed. This has happened in the case of the British Group of the American Association of Cost Engineers. Cost engineering has hitherto been one of the chemical industry's best-kept secrets. No individual manufacturer is happy to divulge how he arrives at costs or how costs have changed over the years. He will claim that, by divulging such costs, valuable know-how is imparted to his competitor; hence the curtain of secrecy.

A number of British cost engineers have long felt that this state of affairs was unhealthy and thereupon proposed to the well-known American Association of Cost Engineers to form an affiliated British Group. This Group was recently formed and held its first annual general meeting which was attended by nearly 100 people. This is a most satisfactory start and the elected chairman, Mr. John Herbert, feels confident that membership should increase rapidly during the next three years. Quite sensibly, the immediate activities of the Group are carried out by small technical committees whose responsibilities are compilation of cost indices, fundamental analyses of capital cost estimation and definition, terminology and other topics of basic importance to those concerned with cost estimating.

This body fulfills a need whose importance can hardly be exaggerated. Industry, we feel sure, will co-operate with the Group once it is convinced that membership is representative of all sections—contracting, plant manufacture and chemical manufacture. We in this journal, having published a monthly cost index since 1957 and, judging by the interest this has aroused amongst our readership, look forward to the day when cost data will be freely published for the benefit of all.

2d. folly

LACK of any integrated government fuel policy was once again clearly shown by the Budget proposal to increase the cost of fuel oil by 2d./gal. Ostensibly this tax is devised to act as a fillip to the coal industry and a disincentive to industrial consumers of petroleum fuels; but this pre-supposes that such fuel oils are used exclusively for heating boilers and furnaces and not for gas-making. Whilst it might be possible (though hardly efficient) for oil-burning boilers to be converted to coal, it would be practically impossible to convert existing oil-gas plants to using coal instead.

Because of the particular difficulties that the gas industry (which is nationalised like the coal industry) is facing at present, this new tax may just act as the ' straw that broke the camel's back '. Designing and constructing gas-making plants is a long-term business and inevitably much depends on accurately forecasting future trends. Throughout the past decade, gas-making plants have been designed for various processes (*Onia-Gegi* and *Segas*) which gasify and reform cheap fuel oils to town gas specifications using liquefied petroleum gases (which presumably escape the tax because they are not liquid at room temperature). With the 2d./gal. tax on fuel oils, it is doubtful whether town gas can still be made as cheaply from petroleum fuels. What will now happen to the oil-gas plants ? Are they to be closed down or will the government devise another subsidy to prevent this from happening; giving to Peter what was robbed from Paul ?

This is the dilemma which is facing the gas industry at present. However efficiently new gas plants are designed, they may be made completely uneconomical to operate simply because a government tax has been imposed on a primary fuel to placate interests in a different industrial sector. Surely this is not the way to create a national fuel policy—it may sometimes be wondered whether the government is at all interested in creating any viable fuel policy which will take into consideration every sector of the industry.

Oxygen in the space age

DEFINITELY topical, in our opinion, is a recently announced development of a complete oxygen recovery system for converting an astronaut's breath into breathable oxygen. At the annual meeting of the Institute of Environmental Sciences, J. F. Foster and J. S. McNulty described such an oxygen recovery system, which consists of three parts:

(1) A plant to recover exhaled CO_2 from the cabin of a space vehicle.
(2) A plant to convert the CO_2 into C and H_2O.
(3) A plant to electrolyse the water into oxygen and hydrogen.

Foster and McNulty reported that they had completed a working prototype of a plant that converts carbon dioxide into carbon and water. The principle of this plant is based on an adaptation of the well-known process formerly used to manufacture fuel gas from coal. CO_2 fed in at the rate of 500 cc./min. reacts with hydrogen over a heated iron-containing catalyst (steel wool and iron oxide pellets) to produce water vapour and solid carbon. The condensed water vapour is then fed to an electrolytic cell, at present being developed, where it is broken down into oxygen and hydrogen. The hydrogen reacts with more CO_2. Carbon is removed from the reactor every few days.

The prototype is less than 5 ft. high, occupies 2 sq. ft. of floor space and weighs about 200 lb. It is therefore quite suitable for inclusion in a space capsule and would seem to be a most attractive alternative to storage of large amounts of oxygen.

Spray-dried Lithopone

By F. Molyneux,* Ph.D., B.Sc.(Lond.), B.Sc.(Eng.). A.M.I.Mech.E., A.M.I.Chem.E.

The rapid increase in consumption of lithopone by the paint industry has drawn attention to its manufacture. One of the most important stages in its manufacture is the drying operation which is conventionally carried out on tray dryers. In this article a new process design for a spray dryer is described, based in one case on heat transfer and in the other on mass transfer. The assumptions underlying this design and the advantages of spray drying for lithopone are fully examined.

LITHOPONE or, to use the trade name of *Orr's Zinc White*, under which it is more easily recognisable, has been manufactured in the U.K. since 1874.

The British Standard Specification for this pigment is that it be 29%ZnS, 70%BaSO₄ with not more than 1%ZnO; it is formed by precipitation from solutions of zinc sulphate and barium sulphide.

In 1935 the consumption of lithopone in the U.K. was 40,000 tons as ZnS, and in the U.S. 150,000 tons. Since this date consumption and production have trebled in this country in spite of the inroads made by the newer pigments such as titanium dioxide.

Manufacture of lithopone

The raw materials are roasted zinc blende, galvaniser residues, zinc ashes or other waste material, and barytes.

The former is dissolved in H_2SO_4 and the solution purified, particularly to remove chlorides, with a soluble sulphide, with zinc dust and with permanganate or chlorate to remove the iron.

The barytes is reduced to give a concentrated solution of barium sulphide by heating with low-grade coke or other fuel and leaching the resulting mass.

The equation for this reduction is:

$$BaSO_4 + 4C = BaS + 4CO$$

Equivalent volumes of the hot solutions are mixed and a heavy mixed precipitate results which is 28 to 30% zinc sulphate and 70-72% barium sulphate, according to the following equation:

$$ZnSO_4 + BaS \rightarrow ZnS + BaSO_4$$

Up to 1920 the darkening of lithopone was a problem, and this was found in some cases to be due to the presence of contaminating metals which form dark-coloured sulphur compounds, particularly those which are susceptible to double decomposition with the light-sensitive zinc sulphide.

These are lead, thallium and manganese in particular, whilst iron, nickel and cobalt are not so objectionable. Contributory causes are the presence of chlorides in the zinc waste and hence great attention must be paid to the purification of the zinc sulphate solution used for lithopone manufacture by treatment with soda ash, soluble sulphides, chlorate or permanganate and with zinc dust.

In other cases the conclusion has been reached that darkening is due to reduction to metallic zinc and probably free sulphur on exposure to light, and that the rewhitening effect experienced in the dark is due to oxidation of the free zinc.

Among other methods of rendering lithopone light-proof is the addition of small amounts of salts of vanadium, chromium and tungsten, phosphoric acid or, perhaps, best of all, trisodium phosphate, and substances that readily yield sulphur, such as mixtures of thiosulphate sulphites and polythionates with ammonium salts.

The precipitated compound of zinc sulphide and barium sulphate as prepared from solutions of zinc sulphate and barium sulphide in water has but little covering power, but it was discovered in 1880 that heating the product to red heat and plunging it in water, grinding, washing and drying, forms lithopone as a satisfactory and durable pigment.

Lithopone has now become the most widely sold of the white pigments and has many advantages in that:

(1) It is brilliantly white.

(2) It is extremely fine.

(3) It has more hiding power than zinc oxide.

(4) It is cheap.

It is particularly well adapted for use in interior coatings, finding extensive use in washable distempers, in white paint pigments and as a valuable filler for heavy paper, oilcloth, linoleum, rubber, textiles and leather manufacture.

The method of manufacture is shown diagrammatically on the attached flowsheet[1] (see Fig. 1).

Operations

The heating or calcining is probably the most important operation in the manufacture of lithopone and must take place at a high temperature closely controlled at 725° to 750°C. in an electrically heated muffle furnace.

Unless the lithopone precipitate from the initial mixing is dried in a uniform non-dusting form it is almost impossible to prevent the surfaces of the muffle from caking up and thus preventing close temperature control and producing non-uniform calcining of the dried product.

With the conventional type of dryer this uniformity of drying is very difficult to achieve and led to consideration of a spray dryer for this, since the spray dryer has the following characteristics:

(1) Gives a relatively uniform product at relatively high rates of drying.

(2) Time of contact is low but the thermal efficiency is also low, unless special precautions such as preheating and recirculation are introduced.

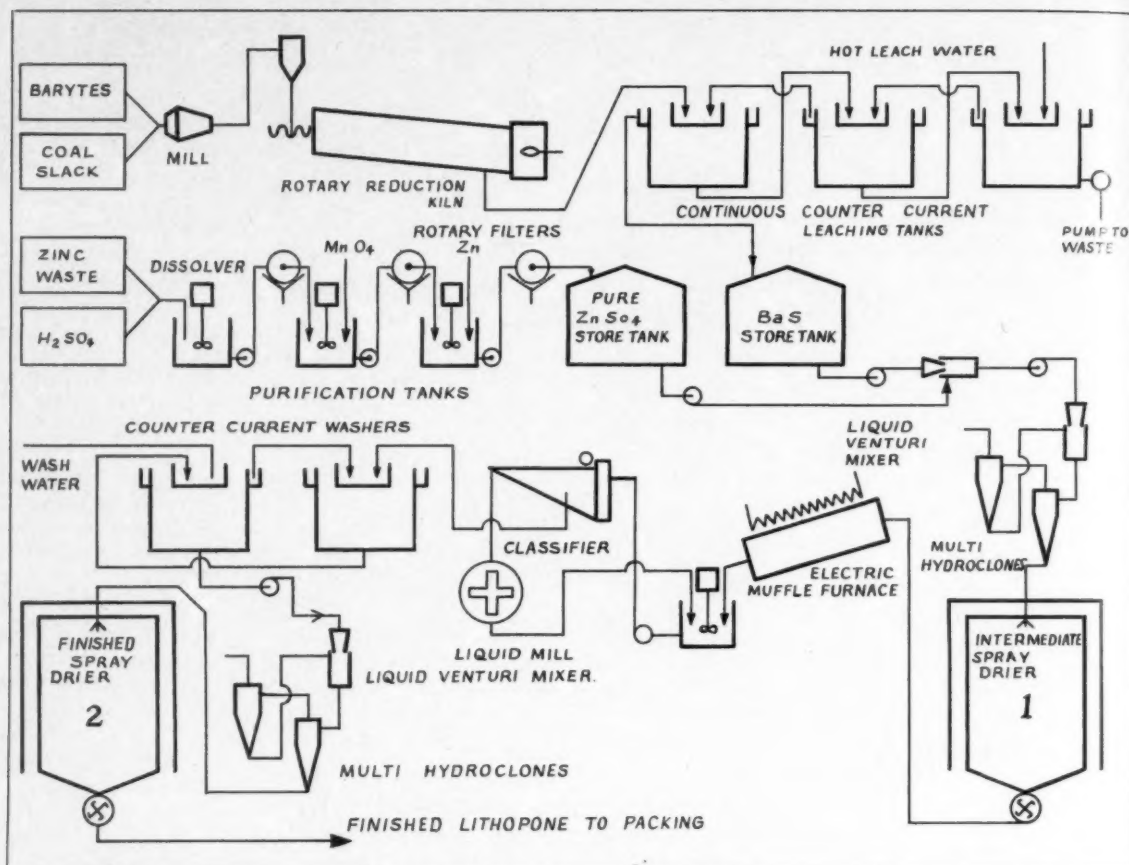*Senior Lecturer in Chemical Engineering, Birkenhead College of Technology.*

Fig. 1. Schematic flow diagram lithopone manufacture

(3) Sufficiently flexible to handle a wide range of products or feeds of varying character and composition.

(4) No metallic contamination since there is only limited necessary contact with metal surface during actual drying.

(5) Easy to clean.

(6) Requires little labour once steady conditions of operation are attained.

The process design of a suitable venturi jet mixer has been considered in previous articles,[2] as also has the process design of a suitable hydrocyclone extraction system.[3]

To complete the process study it was decided to proceed with a process design of a suitable type of spray dryer both for the important drying operation prior to calcining and quenching stage, and also as a final stage to prepare the lithopone in a suitable state for incorporation as a white pigment base, but also in an attractive non-dusting form for sale as an intermediate with a low-bulk density.

Process design of spray dryer

It is desired to spray dry lithopone at a rate of 2,000 lb./hr. from a slurry containing 50% solids.

The inlet air conditions are to be:

Air temperature .. 500°F.
Humidity .. .. 0.010 lb. water/lb. dry air

Outlet air conditions:
Air temperature .. 280°F.
Humidity .. .. 0.060 lb. water/lb. dry air
Wet bulb temperature 126.5°F.
(See Fig. 2)

Droplet size

Volume mean drop size = 100 microns
Minimum drop size = 40 microns
Maximum drop size = 250 microns

Finished lithopone specification

Range of specific gravity between 4.18 and 4.30.
Oil absorption from 10 to 35 lb. oil/100 lb. pigment.
Less than 0.1% retained on No. 325 sieve (Tyler).
The evaporation of a liquid into an inert gas is essentially a phenomenon controlled by diffusional processes.

At the gas/liquid interface there exists a relatively stationary gas film through which the vapour must diffuse, and thus the process of evaporation of a solution can be considered to consist of the following stages:

(a) Diffusion of the liquid through the solution or pasty mass to the liquid interface.

(b) Emergence of vapour molecules from the liquid interface.

(c) Diffusion of the vapour through any solid shell.

(d) Diffusion of the vapour through the stationary gas film.

(e) Removal of the diffused vapour by mass exchange in the main body of the gas.

In all drying operations, including spray drying, there are three main cases, as follows:

(1) Evaporation at the gas/liquid interface, the gas film resistance controlling. This is the period of saturated surface drying and is of prime importance in spray dryers.

(2) Evaporation at the gas/liquid interface, liquid diffusion resistance controlling.

(3) Evaporation at the liquid/solid interface, liquid diffusion resistance controlling, i.e. evaporation occurs in the interior of the particle and the vapour then diffuses through a solid outer shell and also the gas film.

In considering the drying process in spray dryers it is convenient to treat stage (1) separately, as is usually done in other methods of drying. This first period consists of evaporation from a wet surface which remains at the same constant temperature.

This rate can be expressed by a heat- or mass-transfer relationship as:

(1) $$\frac{dw}{d\theta} = \frac{h_c A_L (\Delta t)_m}{\lambda_s} \text{ (heat transfer)}$$

where $(\Delta t)_m$ = mean temperature difference between the air and the drop surface = $(t_a - t_s)_m$.

$\dfrac{dw}{d\theta}$ = evaporation rate mass per unit time

h_c = heat-transfer coefficient for convection and conduction through the film surrounding the drop

A_L = surface area of drop receiving heat

λ = latent heat of evaporation corresponding to t_s.

(2) $$\frac{dw}{d\theta} = K_g A_m (\Delta p)_m \text{ (mass transfer)}$$

where $(\Delta p)_m$ = mean vapour pressure difference
$= (p_s - p_a)_m$
K_g = mass-transfer coefficient.

It is usually assumed that the areas for heat + mass transfer are equal for this first period of drying, and for this period Ranz and Marshall[4] have obtained the following correlations for heat and mass transfer:

$$\frac{h_c x}{k_f} = \left[2.0 + 0.6 \left(\frac{V_a x \rho_a}{\mu} \right)^{\frac{1}{2}} \left(\frac{C_E \mu}{k_f} \right)^{\frac{1}{3}} \right]$$

$$\frac{K_g x p_f}{D_v \rho_A} = \left[2.0 + 0.6 \left(\frac{V_a x \rho_a}{\mu} \right)^{\frac{1}{2}} \left(\frac{D_v \rho_a}{\mu} \right)^{\frac{1}{3}} \right]$$

where x = drop diameter

k_f = thermal conductivity of gas film around drop

D_v = diffusion coefficient of vapour

p_f = mean partial pressure of non-diffusing gas in gas film

V_a = relative velocity between drop and its surroundings

ρ_a = gas film density

μ = gas film viscosity

C_p = gas film specific heat

For zero relative velocity $V_a = 0$.
Equations reduce to:

$$(h_c)_o = \frac{2k_f}{x} \qquad\qquad (K_g)_o = \frac{2 D_v \rho_a}{x p_f}$$

In air/water vapour mixtures this reduces to:

$$(h_c)_o = \frac{0.028}{x} \text{ B.T.U./sq.ft.hr.°F.}$$

For a finite relative velocity

$$h_c = \frac{0.028}{x} \left[1 + 0.27 \, (\text{Re})^{\frac{1}{2}} \right]$$

Kramers[5] has developed the following relationship for the heat transfer from smooth spheres in flowing oil, water and air:

$$\frac{h_m D_o}{k_f} = 2.0 + 1.3 \, \text{Pr}_f{}^{0.15} + 0.66 \, \text{Pr}_f{}^{0.31} \, \text{Re}^{0.50}$$

where h_m = mean heat-transfer coefficient

D_o = sphere diameter

k_f = thermal conductivity of the fluid at film temperature

μ_f = viscosity of fluid at film temperature

C_p = specific heat of the fluid at film temperature

G = mass velocity of fluid

This relationship is valid under the following conditions:

$$10 \; < \text{Nu} < \; 40$$
$$0.7 < \text{Pr} \; < 400$$

and Re up to 10^5.

An alternative correlation has been developed by P. Ayers and J. F. Richardson[12] from experiments on the steady-state transfer of heat between a gas and solids in a rectangular fluidised bed.

For Reynolds numbers between 0.5 and 35 the results are correlated by the equation:

$$\text{Nu} = 0.054 \, \text{Re}^{1.28}$$

The transfer in this case takes place at the bottom of the bed in a shallow zone above which there is no vertical temperature gradient.

Unfortunately, this does not reflect accurately the conditions which are maintained in a spray dryer where the heat transfer takes place in true countercurrent manner from inlet to outlet of the chamber, the gas being always in intimate contact with the solid, though this correlation applied reasonably satisfactorily to the results obtained by Johnstone et al.[13] from experiments on heat transfer to clouds of small particles, somewhat similar to conditions in the spray dryer.

For an initial droplet size of 100 microns the coefficient varies from 85 to 300 B.T.U./sq.ft.hr.°F.

Since the spray-drying operation is a combination of mass and heat transfer, the process design was based on both operations carried out separately. It is found that the drops created by the atomiser device almost instantaneously adopt a constant falling velocity, which in still air approximates to the Stoke's law velocity given by:

$$V = \frac{\rho_1 - \rho_2}{18\mu} g x^2$$

where g = acceleration due to gravity

V = terminal velocity, ft./sec.

$\rho_1 \, \rho_2$ = densities of the particle and air respectively

μ = viscosity of the air

x = droplet diameter

The values for particles of lithopone, density 4.24, are given:

Diameter in microns ..	10	30	60	90	120
Terminal velocity in ft./sec.	0.034	0.365	1.31	2.96	5.25

The density and also the diameter of the droplet vary as evaporation proceeds and for an average density of

droplet at start of 2.62, droplet size 100 microns in contact with air at outlet conditions, the terminal velocity would be 2.1 ft./sec. For the droplet at outlet density 4.24, droplet size 85 microns, in contact with air at inlet conditions, the terminal velocity is 2.6 ft./sec., the average velocity of fall being 2.35 ft./sec.

During their fall the drops transfer moisture to the air and the heat necessary for this is transferred from the air to the liquid film surrounding the drop.

Heat-transfer basis

Working on a heat-transfer basis only, it is therefore necessary to know the amount of heat Q transferred to a drop of a given size per unit time. This amount of heat is given by the equation:

$$Q = h_m A_m (\Delta t)_m$$

If the amount of heat which is required $(= Q^\star)$ is also known, then the falling time can be determined from the quotient $Q^\star/Q$, where $Q^\star = \lambda \times$ total wt. of water evaporated.

The falling time and falling velocity then give the height of the fall, and hence the vertical dimension of the spray dryer, 1 micron $= 10^{-3}$ mm.

$$Q = 200 . 4\pi \left(\frac{92.5}{2} \times \frac{10^{-3}}{25.4 \times 12} \right)^2$$

$$\frac{(500 - 126.5) - (180 - 126.5)}{2.3 \log (373.5/153.5)}$$

$$= 200 . 4\pi (1.82 \times 10^{-4})^2 \frac{220}{2.3 \times 0.39}$$

$$= \frac{200 . 4\pi . 3.32 \times 220}{10^{-4} \times 2.3 \times 0.39} \text{ B.T.U./hr.}$$

$$Q^\star = \frac{1,000 \times 2.62 \times 62.4 \times 4\pi}{6} \left(\frac{92.5}{2} \times \frac{10^{-3}}{25.4 \times 12} \right)^3$$

$$= \frac{1,000 \times 2.62 \times 62.4 \times 4\pi \times 4.4}{6 \times 10^{12}} \text{ B.T.U./hr.}$$

Then $\dfrac{Q^\star}{Q}$

$$= \frac{1,000 \times 2.62 \times 62.4 \times 4\pi \times 4.4 \times 10^8 \times 2.3 \times 0.39}{200 \times 4\pi \times 3.32 \times 220 \times 6 \times 10^{12}}$$

$$= x \text{ hr.} \times 3,600 \simeq 19 \text{ sec.}$$

At a terminal velocity of 2.35 ft./sec. this gives a chamber height of 45 ft.

The volume of the chamber can be determined from a mass balance equation across the dryer.

$$G(H_2 - H_1) = W(M_1 - M_2)$$

$$G(0.06 - 0.01) = \frac{4,000 \times 50}{100}$$

$$G = \frac{4,000 \times 50}{100 \times 0.05} = 40,000 \text{ lb./hr.}$$

The average volumetric gas flow between inlet and outlet conditions $G_c = G . V_{AV}$
where V_{AV} = average specific volume
Inlet specific volume = 25 cu.ft./lb.
Outlet specific volume = 18.3 cu.ft./lb.
Then $V_{AV} = 22$ cu.ft./lb.
$G_c = 40,000 \times 22 = 880,000$ cu.ft./hr.
With a residence time of 19 sec.

Chamber volume $= \dfrac{880,000 \times 19}{3,600} = 4,650$ cu.ft.

Dimensions of chamber: 12 ft. diam., 45 ft. high.

The results given by this method of calculation can only be approximately correct since very wide assumptions have been made, for example that the drying is at constant rate only and that the velocity is the Stokes law terminal velocity.

An investigation by J. Dlouhy and W. H. Gauvin[6] has revealed, however, that where the internal diffusional resistance in the particles is absent due to their small size no significant falling-rate period can be observed, and it is interesting to compare the process dimensions obtained with those for a commercial spray dryer.

Spray dryer dimensions: 18 ft. diam. $\times$ 18 ft. high chamber with centrifugal disc atomiser.
Feed lithopone as a slurry with 73% water.
Air temperature inlet to dryer, 470°F.
Air temperature outlet from dryer, 140°F.
Evaporation rate, 1,750 lb./hr.
12-in. diam. atomiser disc at 3,000 r.p.m.

Mass-transfer basis

A check can be made using a mass-transfer correlation since the operation is a combined mass/heat transfer.
Using the constant rate equation only:

$$\frac{dW}{d\theta} = K_g A_m (\Delta H)_m$$

where K_g = Overall mass-transfer coefficient of mass transfer
A_m = mean area of film
$(\Delta H)_m$ = mean humidity difference across the film
$\dfrac{dW}{d\theta}$ = evaporation rate mass/unit time

Van Krevelen and Hoftijzer[7] have shown that for spherical drops freely suspended

$$\frac{K_g d}{DV} = 0.5 \left(\frac{dV\rho}{\mu} \right)^{0.5} \left(\frac{\mu}{\rho D} \right)^{0.2}$$

Considering the constant-rate drying period only for the evaporation at any small element of chamber volume dZ where the total humidity is H, then

$$\frac{dW}{d\theta} = K_g a_V (H_w - H) dZ$$

where a_V = interfacial surface of contact/unit volume
H_w, H = saturation and gas humidity respectively
If the gas rate G lb./hr. is fixed, the moisture lost by the solid equals that gained by the air, so that

$$\frac{dW}{d\theta} = G \, dH$$

Substituting for dW and rearranging

$$\frac{dH}{H_w - H} = \frac{K_g a_V p_f}{G} dZ$$

and integrating between the humidities at inlet and outlet of the dryer H_1 and H_2

$$\int_{H_2}^{H_1} \frac{dH}{H_w - H} = \frac{K_g a_V p_f}{G} Z$$

where Z = height per unit area of dryer.
The L.H.S. of this equation must be integrated graphically in the normal manner to give the height of the chamber knowing all the other factors.

For air the Lewis relationship holds, thus $\dfrac{K_g C_p}{h_c} = 1$.

Then $K_g = \dfrac{h_c}{C_p} = \dfrac{200}{0.24}$

$$\int_{H_1}^{H_2} \frac{dH}{H_w - H} = 0.86$$

$$a_V = \frac{4,000 \times 4\pi r^2}{(4/3)\pi r^3 \times \rho_d \times G_c}$$

$$= \frac{4,000 \times 4 \times 2 \times 25.4 \times 12}{92.5 \times 10^{-3} \times 2.62 \times 62.4 \times 8.8 \times 10^5}$$

p_f = pressure factor $= \dfrac{p_{B_2} - p_{B_1}}{ln\,(p_{B_2}/p_{B_1})} = 0.96$

$$Z = \frac{0.86 \times 40,000 \times 92.5 \times 10^{-3} \times 2.62 \times 62.4}{200 \times 4,000 \times 3 \times 2 \times 25.4 \times 12 \times 0.96}$$

$= 72$ ft.

This figure is considered to be excessive, due to the fact that the mass transfer is not solely diffusional but is 50% eddy mass transfer and the effective surface area due to this is twice that featured above.

Then effective height = 36 ft.

Chamber dimensions then for residence time of 15 sec.:

$$D = \sqrt{\frac{4}{\pi} \times \frac{880,000 \times 15}{3,600 \times 36}}$$

= 11 ft. 6 in., say 12 ft. diam. × 36 ft. high.

This ratio of height to diameter is not satisfactory and can be attributed to the use of a terminal velocity for the Stokes law fall in still air. The actual relative velocity is much less than this can can be generally described by the equation:[8]

$$V_f = \frac{0.153 \times {}^{1.14}g^{0.71}\,(\rho_L - \rho_a)^{0.91}}{\rho_a^{0.29}\,\mu^{0.43}}$$

The use of this value gives a tower 30-ft. high × 15-ft. diam. with a falling time of 30 sec. for the mean droplet size of 100 microns.

Mechanical design of spray dryer

The operation of a spray dryer involves three fundamental considerations, which are:

(1) Atomisation
(2) Spray gas mixing
(3) Drying of liquid drops.

Spray dryers consist, therefore, of the following essentials:

(1) A drying chamber
(2) Means of atomising the liquid slurry feed and
(3) Source of hot gases.

The design of the dryer itself should incorporate means for separating exhaust gas and dry product, as well as various special devices such as, for example, provision to keep the chamber walls cool.

Either co-current or counter-current flow can be used for the hot gas and feed, but for ease in design most of the spray dryers operate in co-current.

Atomising devices are of two main types, these being either:

(1) Press spray nozzles or
(2) Centrifugal disc atomisers.

These features have been carefully considered by several authors, notably Lewis[9] and Philip[15], and very extensively by W. R. Marshall, Jun.[10, 11]

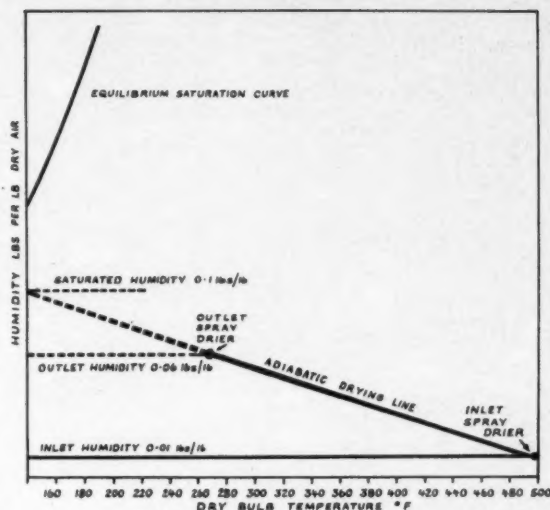In the particular case under consideration it was decided

Fig. 2. Drying chart air/water vapour

to recommend counter-current flow (see Fig. 3), contrary to normal practice, the reasons for this being:

(1) The hottest, driest gas meets the hot/driest lithopone. This tends to keep the humidity driving force constant and thereby more nearly constant-rate drying conditions throughout.
(2) The danger with lithopone is that of contamination and, by introducing the drying gas at the top of the cone, the action is to force the dry lithopone away from the collecting walls.

Lithopone as a 50/50 slurry is rather sticky and, under pressure, tends to show thixotropic properties. It was therefore felt that a pressure nozzle atomiser would not be very satisfactory and a centrifugal disc atomiser was therefore recommended.

Because of this fact, *i.e.* that lithopone is rather tacky, it is easily formed in the shape of hollow spheres by atomisation and by subsequent drying. This property of film-forming substances is increased by increasing speed of centrifugal atomisation and, since it was felt that this form gives some difficulties in drying, *e.g.* explosion of the liquid core, and had no particular virtue from the consumer viewpoint, it was felt that a speed of no more than 3,000 r.p.m. could be recommended.

The power requirements of centrifugal disc atomisers vary with the speed and capacity and are given by the following expression:

$$P = 1.04 \times 10^{-8}\,(rN)^2\,W$$

where P = net horsepower. To this must be added the power due to transmission and motor inefficiencies and disc windage
r = disc radius, ft.
N = revolutions/min.
W = feed rate, lb./min.

In addition to the basic requirements of a drying chamber and atomiser, the spray dryer will require a source of hot air and, in the case of the lithopone dryer, this is most conveniently provided in the shape of a Peabody type air heater consisting of a refractory brick combustion chamber surrounded by an annulus through which cold air is drawn to be preheated by the outer surface of the combustion chamber, and then finally mixed with the combustion exit gases to give a stream of hot gas.
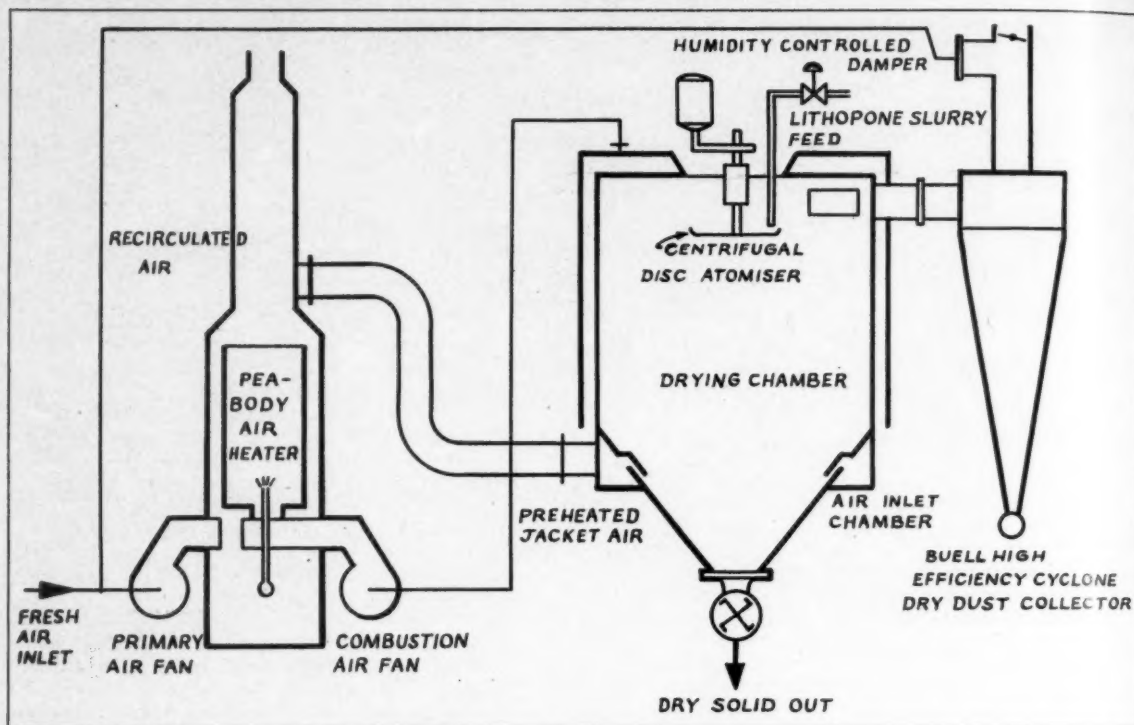
Fig. 3. Spray dryer with countercurrent flow and recirculation

With the normal tray dryer used in lithopone manu-facture, to avoid contamination it is essential to construct all metal parts in either aluminium or stainless steel. With the spray dryer this is not necessary, since there is no contact with metal parts during the drying operation.

The spray dryer can conveniently be housed in the open and this frequently leads to reduced costs.

Auxiliary spray-drying equipment includes:

(1) Special methods of maintaining the walls of the drying chamber cold. This consists of an envelope around the dryer chamber, cold air being drawn through the annulus, keeping the walls cold and preheating the air prior to entering the heater and then the dryer.

(2) Control systems on the dryer feed. Spray dryers can be effectively controlled by controlling the rate of feed to produce a definite outlet gas temperature. This temperature is exceedingly sensitive to variations in feed rate because the gas mixture requires only 5 to 30 sec. to pass through the chamber.

(3) Other controls to maintain the liquid feed at constant composition and temperature.

(4) Dust collectors on the outlet gas from the spray dryer. In this case a dry dust collector was used, since a recirculation fan is placed on the outlet from this.

The thermal efficiency of the spray dryer is rather low, since it is not economic to work with the outlet gas approaching saturation. This can, however, be improved by preheating and by recirculation of the exhaust air, and feeding this as combustion air to the dryer air heater. The amount of this air is controlled to give the required steady inlet and outlet gas conditions.

Before the drops in a spray-drying plant have reached their terminal velocity they have often had a much higher initial velocity. This is the case with the rotary disc atomiser described in this article where the drops leave the disc at a very high horizontal velocity, but these drops are very rapidly braked down by the air, this, however, being accompanied by very considerable evaporation.[14] This is particularly the case with co-current spray dryers where the humidity driving force is a maximum and in some cases can lead to damage of the product due to this rapid evaporation leading to the formation of a hard skin on the particle.

This evaporative step, which is ignored in the develop-ment of this design, can explain the discrepancy in the analytical results achieved and, if incorporated according to the predictions of Sjenitzer,[14] will, in fact, lead to a closer agreement with practice.

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Stop Valves—Some Recent Trends

By A. D. J. Lucas*

Stop valves can be classified amongst the most important pieces of equipment in the chemical process industry. Due to the large numbers of different types of valves it is often difficult for the chemical engineer to select the most suitable stop valve for his requirements. This article therefore describes recent trends in the design and use of gate, diaphragm, pinch, plug and butterfly valves.

WITH so many types of stop valves readily available, it is often difficult for the chemical engineer to decide which one is best suited to his particular requirements. It may, in fact, frequently happen that the most suitable valve is overlooked in favour of one with which the user is more familiar. The purpose of this article is to outline the various types of valves which are generally accepted in the chemical industry and to indicate the particular uses of each type.

This article is primarily concerned with stop valves; all other types of valves have been excluded. However, in many cases, valves which have been designed as stop valves are quite successfully employed on services involving flow control.

Gate valves

Probably the most well established and widely used valve in the chemical industry is the gate valve. For many years wedge gate valves have been an accepted means of effecting line closure on process lines and there have been interesting developments in recent years which have ensured pride of place for the gate valve in oil and chemical installations.

Before discussing this novel development, it may be useful to briefly examine the conventional gate valve which has been in regular use in the oil and chemical industry for many years and to note its inherent virtues and weaknesses. Its one virtue, of course, when compared with the globe valve, plug valve and oblique-type valve is that it provides, when open, a full clear bore creating a very low pressure drop across the valve. As against this single virtue there are numerous inherent weaknesses in the conventional metal-to-metal gate valve. Firstly, and this is very important, anyone with experience of valve operation knows that normal gate valves do not hold tight, but begin

to leak after several days' use. This is a well-known fact and project engineers have for years used various methods of attempting to overcome this problem. Sometimes a spectacle plate is fitted behind the valve. The double block and bleeder system utilising two gate valves and a bleed connection has been a common practice. Furthermore, the use of line blind valves to ensure positive sealing is popular throughout the world. All this serves to underline that it has always been commonly accepted that gate valves leak.

The valve manufacturer, however, takes great pains to produce a perfectly smooth finish on the faces of the wedge and seat rings, but corrosion soon transforms this finish to a rough surface. The minimum corrosion on these faces makes satisfactory valve operation impossible; those who have examined valves which have been in hydrocarbon service for even a short time know how speedily corrosion can destroy the seating surfaces of a metal-to-metal gate valve.

Even if corrosion did not destroy the fine seating surfaces, there are other things which will do so. Small pieces of scale and other solids, metallic or otherwise, being carried down the line by the product, are often wedged between the wedge and seat ring so that immediate damage is sustained to the seating areas.

Another inherent weakness in the design of the conventional metal-to-metal gate valve, more particularly on the larger sizes, is that when such a valve has been closed down hard for some time the wedge becomes jammed between the seat faces and the valve cannot be opened. On the larger size valves where remote control electric actuators are fitted this can have serious consequences.

Technical developments in the oil and chemical industries over the last two decades have created a need for
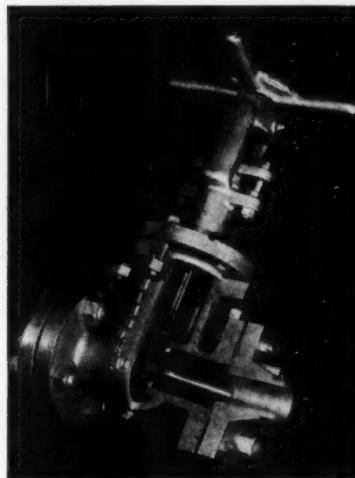
Hindle gate valve

a gate valve which will provide a positive and reliable line closure, and valve designers have spent considerable thought in efforts to produce such a valve. They were considerably assisted in this by the development of the new plastic material, PTFE and fluon, which has been incorporated into a valve of novel design which provides a leakproof seal upstream and downstream. This means that one valve can be used as a double block and bleeder system by merely bleeding off from a plug provided in the body of the valve. Due to the extremely low coefficient of friction of PTFE, all the possibilities of wedges jamming in the body and damage to the seating areas by corrosion in the line have been eliminated.

Lubricated plug valves

The lubricated plug valve, in sizes from ¼ in. to 24 in., is used in a wide variety of chemical plant applications, its simple construction making it

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*Audco Ltd.

ideally suited to handling solids and slurries as well as the more common liquid and gaseous services. Being basically of the plug cock design, the sealing surfaces of the plug and body are not exposed to the line fluid when the valve is in the open position, so the effects of corrosion and erosion are limited. Also, since there is a straight path through the valve, there is very little resistance to flow, and pressure losses are minimised.

In valves employing tapered seating surfaces, the plug is carefully lapped into the body and a high degree of leak tightness is obtained. Furthermore, the use of tapered seats allows the plug to be so adjusted that leak tightness can be accompanied by easy operation of the valve.

Lubrication of the seating surfaces is effected by means of specially compounded valve lubricants which can be inserted into the valve, either in the form of mastic sticks or by grease gun. Lubrication is carried out while the valve is fully in service, regardless of the line pressure. As well as lubricating in the conventional sense, a valve lubricant effectively completes the seal between the carefully mated seating surfaces and enables lubricated taper plug valves to be employed at pressures up to 5,000 p.s.i. or even higher. Furthermore, if a valve should become stiff to operate due to its being left in one position or to inadequate lubrication over a long period, the lubricant may be employed to build up a pressure at the small end of the plug, thus easing the plug on its tapered seat and making the valve easily operable. Recent advances in the development of valve lubricants have produced multi-purpose lubricants which can withstand most line fluids and one valve manufacturing

Audco ' Standard ' valve

company can now cover the great majority of applications using only two lubricants.

Most plug valves used in chemical plant are made of cast iron, which is successfully employed for a wide range of duties; its use has recently been extended by a surface treatment process known as *Lubecoating*. This treatment provides an absorbant layer on the metal surface which enables the valve lubricant to adhere strongly and, since the lubricant itself is resistant to any attack by the line fluid, the metal is to a great extent protected from corrosion. In one type of valve, which is basically of cast iron, the seating surfaces are provided with a sulphate-resistant coating. This valve is widely used on concentrated sulphuric acid duties, the special seats preventing the build-up of interlocking sulphate crystals between the body and the plug which would otherwise cause the valve to become difficult to operate. For more dilute sulphuric acid which cannot normally be handled in cast-iron equipment, plug valves made of an austenitic alloy iron of the high-nickel high-silicon type, such as *Audcoloy*, are successfully employed.

In addition to cast iron, many plug valves are regularly manufactured in carbon steel when high pressures are envisaged, and in austenitic stainless steels. The most common stainless steels are the 18/8 chrome-nickel steel and the 18/10/3 chrome-nickel-molybdenum steel, but whichever grade is employed it is usual to provide some form of hard-facing on the valve plug to prevent galling when the valve is operated. The hard-facing material is normally an electrolytically deposited layer of pure hard chromium or a welded-on layer of a chromium, cobalt, tungsten alloy such as *Stellite*.
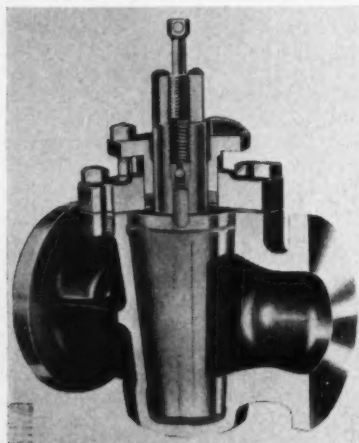
For some corrosive services, plug valves are manufactured with all internal parts coated with resistant plastics. Ebonite has for some time been used as a coating material on such services as hydrochloric acid, wet chlorine and corrosive salt solutions. More recently, thermosetting phenolic resins and thermoplastic polymers have been successfully used as valve coating materials and these have opened up new possibilities in the economic handling of highly corrosive fluids. It is probable that many services which have hitherto necessitated the use of valves of fairly expensive materials, such as stainless steel or acid-resisting bronze, will in future be handled in plastic-coated cast-iron valves.
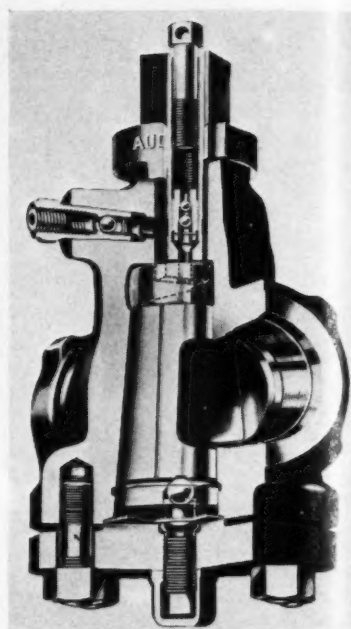
Audco ' Hypreseal ' valve

A further recent important advance in plug valve design has been the use of a tapered sleeve of PTFE between the sealing surfaces of the plug and body. PTFE is resistant to all chemicals except fluorine and the molten alkali metals, and its extremely low coefficient of friction enables the valve to be easily operated without the necessity for a conventional valve lubricant. There is virtually no possibility of the plug sticking in the body and, since lubrication is not required, a valve of this type is in effect maintenance free.

Although all lubricated plug valves share the same basic design, a number of variations are introduced to suit the wide variety of duties upon which they are used. For example, the *Hypreseal* design, which is employed on high-pressure applications up to 5,000 p.s.i. or more, has an inverted plug which is seated upwards into the body by means of a pressure screw in the base of the valve. The use of a pressure screw in this way enables the plug to be positively seated against high-line pressures and complete leak tightness is ensured. At the upper end of the plug, the conventional gland-sealed shank is replaced by a screwed plug stem which passes through a threaded section on the valve body. Leakage past the screwed stem is prevented by packing the threads with a plastic stem-packing compound, which is inserted through a feed unit on the side of the valve.

An equaliser ring (similar in principle to an Oldham coupling) between the plug and the plug stem permits the small endwise movement of the stem during rotation and prevents any side load on the plug (due to high line pressures) being transmitted to the stem.

The plug valve is also ideally suited for multiport applications and a number of multiport designs are readily available. In the simplest case a three-way valve fitted with a plug having an 'L'-shaped port is used to divert a flow from one pipeline to another. The use of a 'T'-shaped plug port enables a number of other flow positions to be obtained.

Fourway valves, having double 'L' ported plugs, are also available in a wide range of materials and it is frequently possible to bring about considerable simplification of pipework and substantial valve economy by the use of valves of this type.

Most plug valves are normally operated by means of a simple wrench or in larger sizes by worm gear and handwheel, but there is a growing need for power-operated valves and a range of actuators has been developed to meet this demand. The commonest form of plug valve actuator comprises a pneumatic cylinder and piston linked to the plug shank by a totally enclosed rack and quadrant. The unit is completely self-contained and, since it is mounted on the valve itself, there are no forces acting between the valve and any associated pipework or mountings. A normal works air supply at 80 to 100 p.s.i., suitably filtered and dried, is adequate for an actuator unit of this type. Hydraulic operation may also be employed, using a similar type of actuator.

For larger gear-operated valves, an electric actuator can be provided, the complete unit comprising a specially designed totally enclosed worm-type reduction gearbox with integral stator rotor power unit and switch control box.

Power operation can considerably simplify plant operation by enabling valves to be remotely operated, if required, from a single central point, and appreciation of the advantages of this type of operation is rapidly increasing.

Diaphragm valves

From an invention, which was first used in the gold mines of South Africa to handle compressed air, the diaphragm valve has been developed and accepted as a particularly efficient means of controlling the many difficult and specialised fluids of modern industry.

The principle of the valve involves a flexible diaphragm which closes the pipe against the flow of the fluid. Not the least important virtue of this principle is that the fluid in the pipe is permanently sealed against external contamination and, likewise, the operating mechanism that controls the diaphragm is itself protected from any action of the fluid and can retain its lubrication. Where the fluid may be dangerous and the atmosphere corrosive, these two facts are of immense importance. Developments in diaphragm materials, valve bodies and their linings have multiplied the number of applications until there is now scarcely a manufacturing process that

[Courtesy: I.C.I. Plastics Division
Saunders PTFE-faced diaphragms

does not use diaphragm valves at some stage.

The characteristics of the valve have been particularly appreciated in chemical works where acids, alkalis, gases and solvents must be controlled without risk of leakage. To this end, over 70 grades of diaphragm have been evolved, includi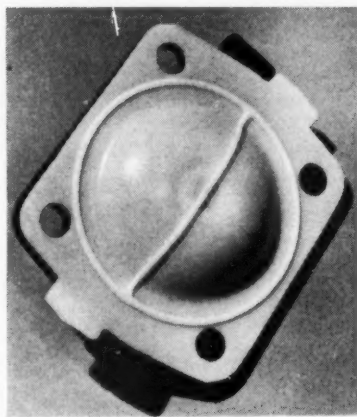ng a grade which has a PTFE facing with synthetic rubber backing. Diaphragms of this sort are available for valve sizes $\frac{1}{4}$ in. to 8 in. Valves of solid PTFE are also available in certain sizes. Since all working parts in contact with the fluid are of PTFE, it is likely that this valve is the most chemically resistant type in service. Typical applications are for concentrated chemicals used for dosing boiler feed water and for chemical effluents.

Maintaining a diaphragm valve consists only of an occasional diaphragm change. This saving in maintenance costs usually far outweighs the price of replacement diaphragms. There is a great variety of methods of operation, from the simple handwheel and lever designs to remotely-controlled power operation (pneumatic, hydraulic or electrical). The size range of the diaphragm valve extends from $\frac{1}{4}$ in. to 16 in. and, since bodies, diaphragms and top works are interchangeable, the possible permutations are indeed numerous.

For handling highly viscous fluids or those having a high solids content, a diaphragm valve of straight bore is often preferred. This design permits rodding or brushing-through to remove obstructions in the line and has minimum flow resistance. Valves of this design are made in sizes $\frac{1}{2}$ in. to 10 in.

At present, 19 different diaphragm valve linings are available including rubbers, metals, various plastics and glass. Hard rubber-lined valves are supplied in greater number than other linings. The reason for this is not far to seek, since hard rubber-lined valves are robust, cheap and have surprisingly wide chemical resistance. In addition hard rubber-lined bodies have good resistance to abrasion, although soft rubber-lined valves are preferable where this is the main factor.
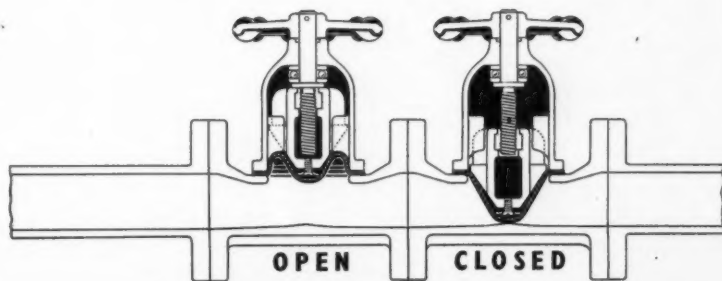
Big users of hard rubber-lined diaphragm valves are steel and tin-plate works on dilute sulphuric acid; indeed, hard rubber-lined valves may be used on sulphuric acid up to about

OPEN   CLOSED

Saunders straight-bore diaphragm valve

78% at room temperature. Maximum recommended temperatures are normally about 85°C. Representative services for hard rubber-lined valves are dry chlorine gas contaminated with sulphuric acid mist, salt brine, spin-bath solutions, pickling lines, electrolytic tinplate lines, dilute acids and effluents. Hard rubber-lined cast-steel valves are handling sea-water at oil refineries.

Because of their abrasion-resistant properties, soft rubber-lined bodies are often specified in the mining, quarrying and other extractive industries; they are also widely used handling phosphoric acid in fertiliser manufacture. Other services encountered include manganese sulphate, ferric oxide, silica sand and other abrasive slurries. The inertness of polyethylene and PVC to many chemicals has been turned to account and valve bodies in these materials are proving economical for many acid services, particularly mixtures containing hydrofluoric acid.

Pinch valves

Pinch valves are the commercial exploitation of the laboratory clip; they consist of a rubber tube and a mechanism for clamping it to reduce or shut off the flow through it. They have been in extensive use in the U.S. for 30 years, but have only been available in this country since the war and are therefore not so widely employed. Their greatest advantage is that when open they provide a completely straight-through full bore which has no protrusions, pockets or cracks to cause a blockage when handling thick slurries or powders. A second advantage is the isolation of the fluid from the operating mechanism. This makes pinch valves very suitable for handling corrosive liquids or any substances where metal contact is undesirable; it also eliminates sticking, which can be such a problem under certain conditions. A feature frequently not appreciated is that of the ability of a soft rubber to resist abrasion. Many cases are on record where a pinch valve has outlived a metal-bodied valve on abrasive duties by two or three times and still only required a new rubber tube instead of a complete replacement. Perhaps the major shortcoming of pinch valves is their unsatisfactory performance on suction duties; the tube tends to collapse or fails to open. It is also not recommended to employ pinch valves on a line subject to pulsation because the tube will tend to 'pant' and suffer flex fatigue.

Most pinch valves produced in this country have a metallic body enclosing the rubber tube and clamping mechanism, but it is usual in the U.S. merely to employ a framework to hold the mechanism in place. This enables the condition of the tube to be readily seen, but when a fracture occurs, there is nothing to prevent the free flow of the liquid, which could be dangerous or at least very inconvenient. It is desirable that valves bigger than 2 in. are clamped to close on the centre-line of the in order to avoid stressing it unduly. It is also advantageous if the handwheel is of the non-rising type which facilitates operation by bevel gear extension, chainwheel or electrical actuator. Pinch valves lend themselves to pneumatic operation for remote or automatic control but have the disadvantage of requiring considerable force to close the tube at even moderate line pressures. A suitable arrangement for on/off duties only, is to employ two opposing air cylinders each operating one pinch bar to close the tube on the centre line, but where intermediate positioning is required a design employing only one actuator must be employed. A patented design is illustrated in which the movement of the top pinch bar is transmitted to the bottom pinch bar through a linkage designed to give rapid closure over the first part of the travel and slow over the latter part. This has two great advantages—it reduces the thrust required to shut off, and considerably improves the valve's characteristics, which approach much nearer to linear than any comparable valve as illustrated.

Pinch valves are available in sizes from $\frac{1}{2}$-in. to 14-in. bore for working pressures up to 100 p.s.i. and to handle temperatures of 100°C. or even slightly more. They may be operated by any of the usual manual methods, pneumatically and electrically. It is reasonable to suggest that they be considered for most duties; naturally, for many applications other types will be chosen because of superior performance or lower cost, but the scope of the modern pinch valve is such that it warrants careful consideration. It is most effective for handling abrasive slurries and powders. The wide range of elastomers now available enables the pinch valve to handle many corrosives. To list the possibilities would be beyond the scope of this article, but the chemical engineer will know whether rubber or synthetic rubber is resistant to the fluid concerned.

Performance and economy are not always the deciding factors in valve
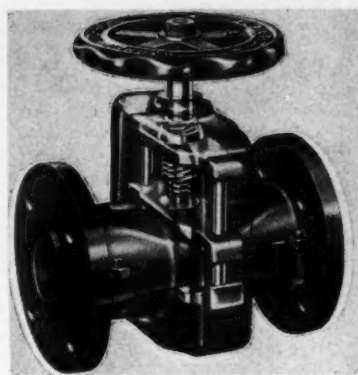
Warren Morrison pinch valve

selection and pinch valves are often specified due to their light weight—the rubber isolates the body, which can conveniently be of light alloy. The resultant valve is convenient for installation and reduces the tare weight when fitted to road vehicles.

Spherical plug valves

Spherical plug valves, contrary to general opinion, are not a new conception, various types having been in existence in industry for 30 years. However, it is only in recent times that full advantage has been taken in the use of technological progress in elastomers and plastics in order to provide a valve which has a more general and competitive application throughout industry. Generally, spherical plug valves can be considered to be those valves in which there is a rotary member of a spherical shape through which a port passes and to which the valve seat is presented. It utilises the basic geometrical advantage of constantly presenting a similar surface to the seat, and the seat itself is of a simple annular form.

There are two main variants in general use. In one the ball plug is divorced from the operating stem and is supported by the seats so that, when in service, the pressure in the line tends to force the upstream seat on to the ball and the ball on to the downstream seat. The other variety utilises a ball plug with trunnion support, of which the one trunnion is the operating member. This design is particularly suitable for the higher pressures since the resultant load on to the ball due to pipeline pressure is borne upon correctly designed journal bearings and only a nominal seat pressure is applied on the sealing member. Both designs can take full advantage of the major strides now being made with regard to chemical-resistant rubbers and plastics, and the
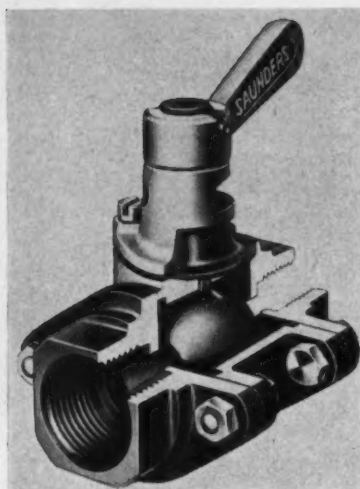
Saunders spherical plug valve

construction of the valve itself can be from widely varying forms, *i.e.* forgings, bar stock, castings, fabrication and, in certain instances, thermosetting plastics.

Spherical plug valves are available in a wide variety and can readily incorporate features applicable to various industries. Sizes range from midget, $\frac{1}{4}$-in., 10,000-p.s.i., panel-mounted valves to 4-ft.-bore high-pressure pen-stock valves. They can be used on ultra-high vacuum services, cryogenic services, various abrasive services and all petroleum or chemical products. Although the majority do incorporate elastomer or plastic seats, variants are available with completely metal seats suitable for high-temperature use.

The obvious advantages in comparison with other valves are low torque, certainty of operation after a period of standing with no sticking tendencies, a clean round opening port which can be venturi design or full area, low weight due to economy of metal, little or no maintenance and, as with other plug valves, 90° operation from fully open to fully shut. In the majority of designs the valve is removed from the line for periodic attention as and when required, but there is a top entry design in which the ball and seats may be taken out *in situ*. In all cases one major advantage is that no expert fitting or assembly is required and balls and seats are completely interchangeable with no bedding-in necessary. At the present time, spherical plug valves are only beginning to make their presence felt in the chemical industry, but undoubtedly their use will increase as they become more widely known.

Butterfly valves

Valves of this type are particularly suitable for isolating duties and may be used to advantage as flow regulating valves on low- and medium-head installations where the duties are not severe. For regulation involving rigorous throttling, for example free discharge to atmosphere, a specialised type of valve such as a needle disperser or regulating valve should be used.

Butterfly valves are amongst the simplest forms of valve and this inherent simplicity makes possible a compact and economical design.

The valve blade or door may be placed symmetrically or unsymmetrically to suit the torque characteristics required. In either case these characteristics are fully known over the whole range of opening and closing as a result of the extensive tests which have been carried out on prototype valves of all types.

In general, it can be said that the butterfly valve lends itself to a wider range of operating devices than most other types of valve. Operation may be performed by means of or a combination of any of the following:

Pneumatic, hydraulic and electrical actuators, as well as the more usual means of normal operation.

They are equally suitable for use with liquids or gasses and, although generally of cast iron or fabricated steel construction, can be produced in a wide range of materials to meet special requirements (corrosion resistance, abrasion resistance or performance at high or low temperatures).

Contrary to widespread belief that butterfly valves are 'balanced' valves requiring very little operating effort, they are in fact subject to hydrodynamic or aero-dynamic forces when they are opened or closed. The magnitude of these forces is largely a function of the velocity of the fluid passing through the valve and must, therefore, be taken into account when rating the valve actuator.

Valves intended for use with corrosive liquids such as sea-water can be provided with neoprene internal coatings. The butterfly valve is particularly suitable for this type of protection as the inherently clean streamlined internal surfaces can be readily and cheaply coated.

Conclusion

It will be appreciated that there are other types of stop valves which are quite extensively employed in the chemical industry, but it is hoped that this article will, by drawing attention to the main trends in valve design, enable the chemical engineer more easily to select the type of valve which is most suited to his needs.
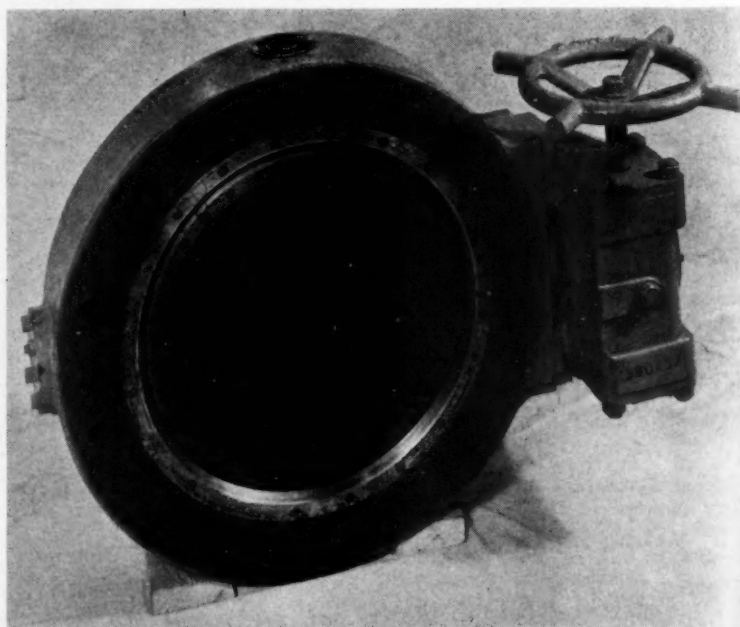
An 18-in. hand-operated Boving butterfly valve

Fig. 5. Trolley-mounted blending unit and meters

Continuous In-line Blending Systems

By R. L. Botting*

In recent years a strong demand by the petroleum and allied industries has necessitated the development of a system capable of blending two oils at a specified ratio without the use of complex instrumentation. It was found that the system must be entirely self-operated, independent of electricity or compressed-air services and preferably portable. This article describes the principles underlying the design of the system and discusses its suitability for blending oils.

THE blending system employs the principle of parallel metering of the two components and arranges that the pressure losses across the two metering areas are kept equal; therefore, for any particular setting of the metering valve the proportional rates of flow of either component remain constant.

The system consists of two sections, the balancing unit and the metering area. The balancing unit consists of two pressure regulating valves actuated by a common diaphragm; the metering area consists of a fixed orifice and a metering valve. The two components to be blended are pumped to balancing valves $A1$ and $A2$, which have a common spindle attached to diaphragm C (see Fig. 1). Pressure tappings are taken just upstream of the

metering area fixed orifice D and metering valve E, at points $B1$ and $B2$ respectively, and are tapped to either side of the diaphragm C. Any inequality of pressure at these two positions will cause the balancing valve assembly to move, altering the pressure losses across these two valves, thus raising the lower pressure and lowering the higher pressure until balancing of pressures $B1$ and $B2$ is complete. The two components then flow through fixed orifice D and metering valve E to a mixing vane at the discharge point F. As the pressure at F is common to both components and pressure at $B1$ and $B2$ is maintained constant, the pressure losses across orifice D and orifice E are equal. The blend ratio, therefore, and ultimate blend viscosity is obtained by

direct proportion of areas across the two metering devices. Since one of these is fixed, the blend ratio may be expressed as a function of the travel of the metering valve.

To enable the unit to maintain a constant blend ratio, a special type of fixed orifice had to be employed. It was decided to employ an orifice based on a design used by Witte[1] in his tests on the flow of viscous fluids, which showed that the discharge coefficient remained relatively constant over wide fluctuations in viscosity. Since it is expected that wide fluctuations in viscosity will occur in the heavy oil component used in the blending of fuel oils due to the fluctuations in pumping temperature,

*Fisher Governor Co. Ltd.

this specially designed orifice is situated in the heavy oil line. The pressure balancing valves consist of a double-ported quick-opening type valve in the heavy oil arm $A1$ and a double-ported high-lift V-port type valve in the light oil arm $A2$, the reason for the difference being due to the low flow rate of the light product at high blend ratios.

The metering valve is of the sleeve and piston type (see Fig. 2) and has an equal percentage characteristic which gives the unit the same order of repeatability and sensitivity of blend ratio over its full travel range. (On the prototype unit the metering valve took the form of a single-ported globe valve fitted with a parabolic plug-type inner valve. This type of valve gave the unit a blend ratio range of from 1 : 1 to 10 : 1, but as the requirements of the industry necessitated a blend ratio of up to 20 : 1, this valve was replaced by the sleeve and piston type valve as described.) The valve is fitted with a handwheel and three-digit counter for readily setting the blend ratio; this gives a very high degree of accuracy and repeatability.

Efficiency

It can be seen from the above that the overall efficiency of the unit is dependent upon the efficiency of balancing pressures just upstream of the two metering areas. The following is a theoretical analysis to show the relationship between pressure balancing and blend ratio (see Fig. 3). In the following, $P1$ and $P2$ are the static pressures just upstream of the fixed orifice and the metering valve respectively, $P3$ is the common downstream pressure at the junction of the heavy and light oil component arms, $\Delta P1$ is the pressure loss across the orifice plate and $\Delta P2$ is the pressure loss across the metering valve.

Let Px = pressure balancing error.
Therefore $P1 - P2 = Px$ .... (1)
Now $P1 - P3 = \Delta P1$ .... (2)
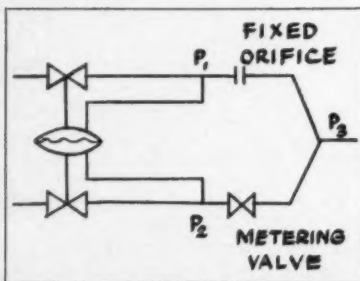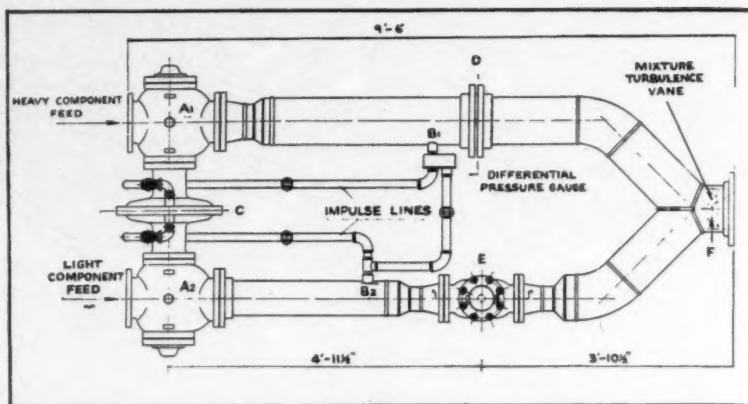and $P2 - P3 = \Delta P2$ .... (3)

Fig. 3

Subtracting equation (3) from equation (2), we obtain:

$P1 - P2 = \Delta P1 - \Delta P2$ ...... (4)
Therefore $Px = \Delta P1 - \Delta P2$ .. (5)

Let Z = pressure balancing error as a percentage of $\Delta P2$. Then

$$Px = \Delta P2 \left(\pm \frac{Z}{100} \right) \ \cdots \cdots (6)$$

Using equation (6) in equation (5), we obtain

$$\pm \frac{Z\Delta P2}{100} = \Delta P1 - \Delta P2$$

Therefore

$$\Delta P1 = \Delta P2 \pm \frac{Z\Delta P2}{100}$$

and

$$\Delta P1 = \Delta P2 \left(1 \pm \frac{Z}{100} \right) \ \cdots \ (7)$$

Blend ratio error

The flow across an orifice can be written as a function of a numerical constant and the square root of the pressure loss across the orifice, i.e.

$$\text{flow} = C\sqrt{\Delta P} \ \cdots \cdots \cdots \cdots (8)$$

where C is a numerical constant.

Therefore, using equation (8), the flow across fixed orifice can be represented as $C1\sqrt{\Delta P1}$ and the flow across the metering valve as $C2\sqrt{\Delta P2}$, where $C1$ and $C2$ are the numerical constants for the fixed orifice and the metering valve respectively.

Let R = ratio of flow across fixed orifice versus metering valve (i.e. blend ratio).

Then using the above,

$$R = \frac{C1\sqrt{\Delta P1}}{C2\sqrt{\Delta P2}} \ \cdots \cdots \cdots \cdots (9)$$

Ideally,

$$\frac{\sqrt{\Delta P1}}{\sqrt{\Delta P2}} = 1 \ (\text{no balancing error}).$$

Therefore,

$$R = \frac{C1}{C2} \ \cdots \cdots \cdots \cdots (10)$$

Using equation (10) in equation (9),

$$R = R\frac{\sqrt{\Delta P1}}{\sqrt{\Delta P2}} \ \cdots \cdots \cdots (11)$$

Using equation (7) in equation (11), we obtain

$$R = R\frac{\sqrt{\Delta P2 \ (1 \pm Z/100)}}{\sqrt{\Delta P2}}$$

Therefore,

$$R = R\sqrt{1 \pm \frac{Z}{100}} \ \cdots \cdots (12)$$

Equation (12) can be written as follows:

$$R = R\left(1 \pm \frac{Z}{100} \right)^{\frac{1}{2}} \ \cdots \cdots (13)$$

Expanding equation (13) using the binomial expression

$$R = R\left(1 \pm \frac{Z}{200} \right) \ \cdots \cdots (14)$$
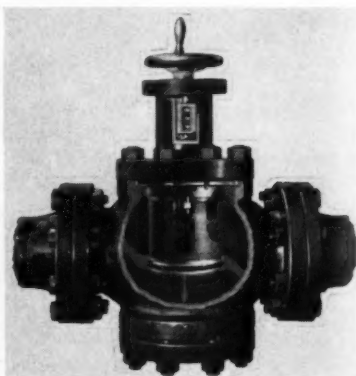
As Z is relatively small, Z raised to

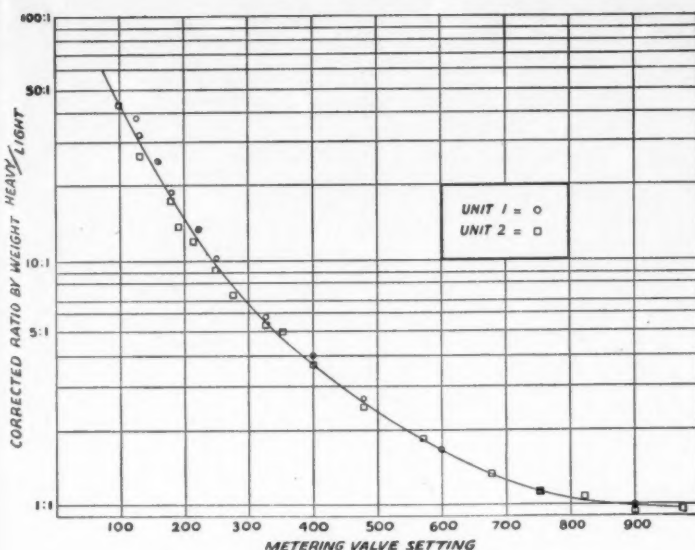Fig. 2. Detail of standard metering valve showing hand-wheel counter and piston-type inner valve

Fig. 1. Schematic arrangement of blending unit

Fig. 4. Results of tests on wide-range blending units

unit in p.s.i. and R is the blend ratio heavy to light by weight.

It can be concluded from the above that for most bunkering requirements this type of blending unit gives a very high degree of accuracy, well within the specified limits for marketing and distributing fuel oil to the industry. However, there are times when small packages and exceedingly low flow rates are required. By referring once again to the analysis it can be seen that there must inevitably be a limiting low flow condition for a given unit (the normal flow turn-down being 5 : 1), i.e. where the pressure loss across the metering area is very small, thereby increasing the value of Z and causing the blend ratio error to be too great for the system to be considered accurate. Further development was required to enable the unit to be used continuously at these limiting flow conditions with a very high degree of accuracy (namely $\pm 1\%$ of viscosity).
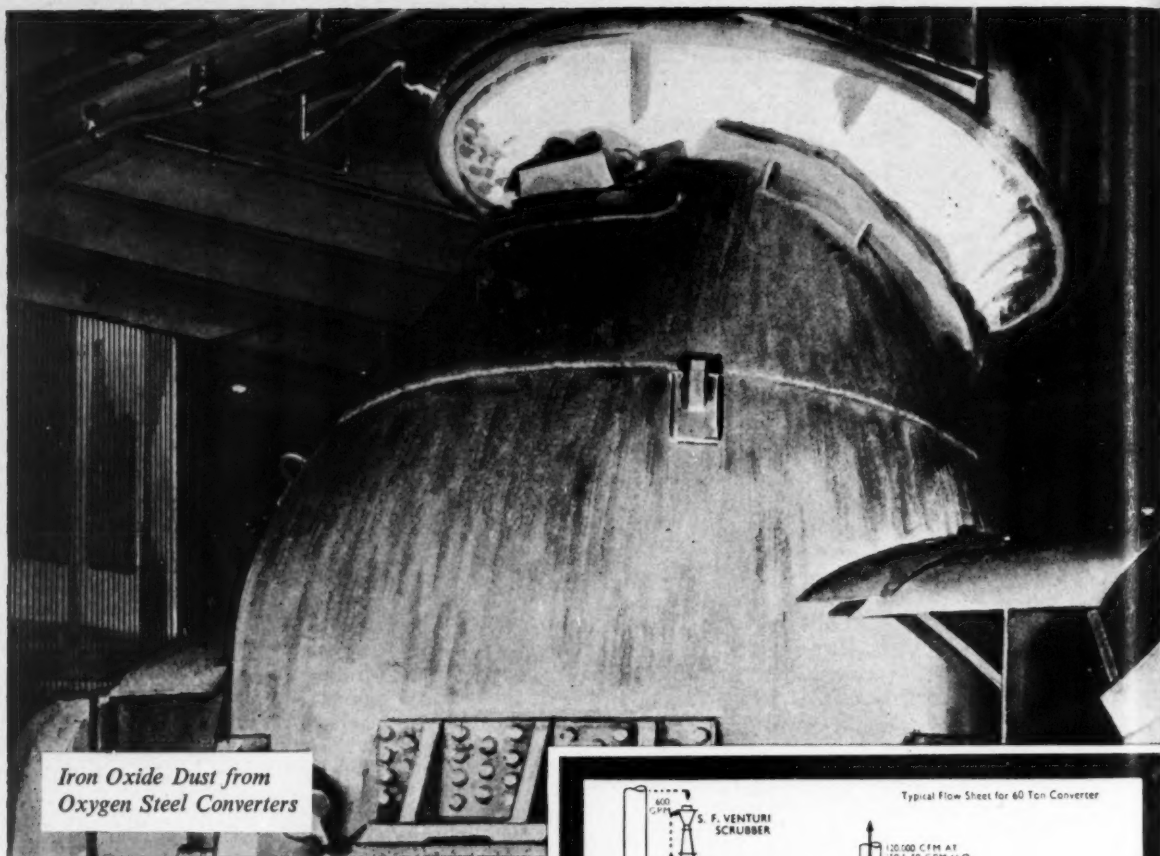
It was considered that, as the blended product is marketed to a viscosity specification, if a continuous indicating type viscometer were mounted on the downstream side of the blender to monitor the stream, it should be possible to use a signal from this to trim the position of the metering valve and therefore retain the high degree of accuracy at these limiting conditions. There is, in fact, one such instrument, the Smith's viscosity comparator, which employs two rotating drum type viscometers to compare the blended product with a standard sample. Any deviation in viscosity of the blend from the standard sample will vary the output torques of the two drums, causing a torque arm to move and operate microswitches, thus giving an on/off signal which is used to operate an electrical actuator mounted on the metering valve, either opening or closing the valve as required.

Conclusions

The blending system described above has been found to give highly satisfactory performance well within the specified limits laid down by the marketing and distribution departments of the petroleum and allied industries. It requires little or no maintenance, even though at times subjected to very rigorous conditions; the unit can readily blend together oils of up to 4,500 Redwood No. 1 seconds; it does not require expert knowledge to operate and therefore does not become a liability.

REFERENCE

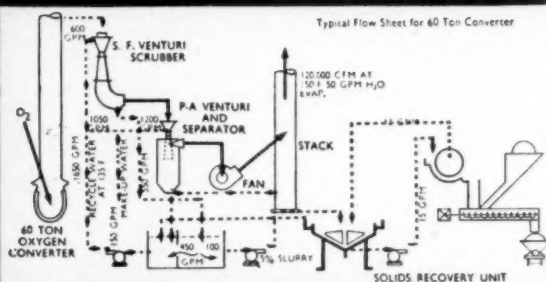[1] Witte, Z.V.D.I., May 15, 1943.

the power of 2 and above can be ignored. Therefore, using equation (14), the flow ratio error can be written as follows:

$$\text{Blend ratio error} = \pm \frac{R.Z}{200}$$

of the percentage error in flow ratio

$$= \pm \frac{R.Z}{200} \times \frac{100}{R} = \frac{Z}{2} \quad \dots \ (15)$$

There the percentage blend ratio error is one-half of the error in balancing, written as a percentage of the pressure loss across fixed orifice.

In any system as described above, i.e. the self-operated type, the balancing error Px is inherent in the design, i.e. basically due to frictional losses (hysteresis) in the balancing assembly. Therefore Px will remain substantially a constant for all flow rates and blend ratios. Therefore as Z is inversely proportional to $\Delta P2$, and as $\Delta P2$ is in turn directly proportional to the square of the flow, it can be said that Z is inversely proportional to the square of the flow. As the flow increases so the percentage error in blend ratio decreases by the square.

The significance of the above was appreciated in the initial design and, in consequence, the inner valves of the balancing unit assembly are mounted in roller bearings to reduce the friction in the assembly to a minimum and give the maximum efficiency of blend ratio.

At first it was thought that each unit would require individual calibration, but on subsequent testing it

was found that the units showed remarkable repeatability (see Fig. 4) and that one setting chart could be drawn for all units. The accuracy claimed, namely 1% volumetrically, therefore embraces the accuracy of the blending system, plus the machining tolerances of component parts. Individual calibration would eliminate the machining tolerances, but as 1% volumetrically is considered sufficiently accurate for most bunkering requirements, the cost of individual calibration is not warranted.

A further development of this system is the manufacture of a completely portable unit which is mounted on a pneumatic-tyred trolley, with the addition of positive displacement type bulk meters to measure the total flow of the blended product. The complete unit has a towing hook, and can be towed with ease behind a suitable vehicle over comparatively rough surfaces (see Fig. 5).

A set of empirical formulae have been compiled to cover the four standard-sized units manufactured, to enable any required set of flow conditions to be satisfied:

Size 3 in., type 431, blending unit:
  Flow = $6\sqrt{\Delta P(1 + 1/R)}$
Size 6 in., type 431 blending unit:
  Flow = $23\sqrt{\Delta P(1 + 1/R)}$
Size 8 in., type 431, blending unit:
  Flow = $37\sqrt{\Delta P(1 + 1/R)}$
Size 10 in. × 6 in., type 431, blending unit:
  Flow = $39\sqrt{\Delta P(1 + 1/R)}$

Where flow is in tons/hr., ΔP is the pressure loss across the whole

Gas Cleaning in the Iron and Steel Industry

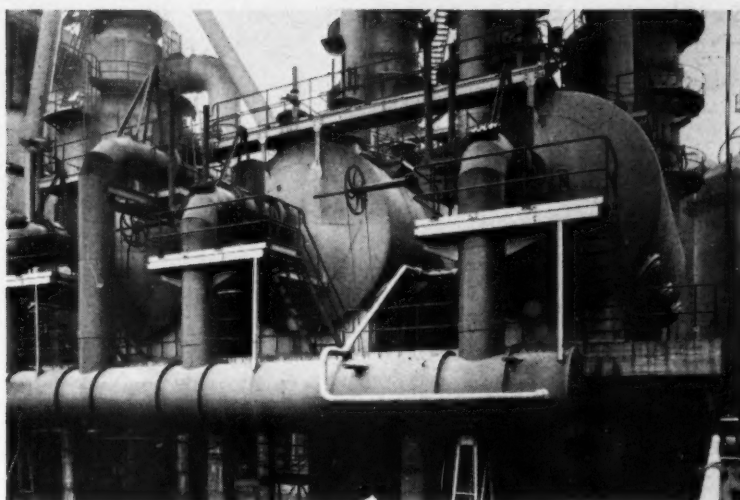**By N. Pilpel, B.Sc., Ph.D.**

Fig. 4. Three Holmes-Elex electrostatic precipitators cleaning blast furnace gases at Bilston works, Stewarts & Lloyds Ltd.

There are over 200 registered works in this country engaged in the manufacture of iron and steel. They range in size from those using small electric arc furnaces with a capacity of 1 ton, to integrated works producing up to 3 million tons of steel p.a. In this article the main sources of dust, smoke and fume in the industry are discussed and an account is given of the equipment and methods that are being employed to limit emission to an acceptable level.

THE main processes that are involved in the manufacture of iron and steel are:

(a) Reduction of iron ore to iron in blast furnaces

(b) Conversion of iron into steel in open-hearth, Bessemer and electric arc furnaces.

Ancillary processes include drying, calcining and sintering of the ore to improve its chemical and physical properties, coke-making, melting, desulphurisation and desiliconisation of iron for castings, deseaming of steel, etc.

In these processes large quantities of dust, smoke and fume are produced and it has been the aim of recent legislation[1] to control more rigorously than before the amounts that are liberated into the atmosphere.

Blast furnaces

In the blast furnace, iron ore is reduced to metallic iron by heating it to a high temperature with coke and limestone. The gas that is evolved may have a calorific value in the neighbourhood of 100 B.T.U./cu.ft. (N.T.P.) and at integrated works is therefore employed as a fuel, being burnt in Cowper stoves to preheat the air entering the blast furnace and being used also for raising steam, for heating coke ovens, soaking pits and open-hearth furnaces, etc. At smaller works, however, the bulk of the gas is allowed to escape without making use of its heating potential.

The gas contains miscellaneous dust from the coke, limestone and ore as well as iron oxide fume. Under normal circumstances this may amount to about 10 gr./cu.ft. Periodically, however, the contents of the furnace slip and there is a sudden release of gas, heavily laden with dust and fume, whose volume is too great for it to be passed through the normal gas-cleaning equipment. Instead the excess is bled directly to the atmosphere through vents at the top of the furnace and this is a major source of pollution, particularly at the smaller, non-integrated works.

A practical solution is to reduce the frequency of the slips, which can be done by:

(a) Regularly lowering the blast rate, which reduces the pressure on the charge and enables it to move more uniformly

(b) Using coke of controlled mesh size to give a more permeable bed

(c) Pretreating the iron ore, for example by sintering, which converts fine dust into hard agglomerates.

There is evidence[2] that in recent years the occurrence of slips has been substantially reduced by these techniques.

The usual method of cleaning the gas from blast furnaces is to pass it first through a cyclone dust catcher. The cyclones that are used are of various design and schematic diagrams are given in Fig. 1.

Dust-laden gas entering at A spirals down to the bottom of the cone. As a result of centrifugal force, the larger particles of dust and grit are flung outwards to the walls and slide down into the hopper below while the cleaned gas flows upwards through the turbulent central region and escapes at B.

Writing η and ρ for the viscosity and density respectively of the gas, σ for the density of the dust, V for the average inlet velocity, β for the diameter of the cyclone inlet and N

for the effective number of spirals made by the gas stream in the cyclone (usually between three and five), the diameter d of particles which a particular cyclone will collect with 50% efficiency has been given[3] by:

$$d = \sqrt{\frac{9\eta\beta}{2\pi NV(\sigma - \rho)}}$$

Particle size

The overall efficiency, however, will depend on the distribution of particle sizes present in the gas and is generally expressed by means of grade efficiency curves. These give the percentage of grit and dust of different sizes removed by the cyclone under standard operating conditions and typical curves are plotted in Fig. 2. As might be expected, the overall efficiency of cyclones varies considerably throughout the course of a blast furnace operation due to periodic changes in the temperature, pressure and volume of the gas, changes in the rate of emission of dust and fume, and changes in its particle size distribution. At some works the gas will enter the cyclone at a relatively low temperature (300°C.). At others its temperature may be as high as 1,300°C. and special cooling with water sprays is needed to prevent buckling and corrosion of the cyclones. As a generalisation, however, cyclone treatment of blast furnace gases reduces its dust content from over 10 to less than 5 gr./cu.ft.,[4] maximum efficiency (about 80%) being achieved on particles greater than about 50 microns in diameter.

Wet cleaning

At the larger works, cyclone treatment is almost invariably followed by some form of wet washing which, in addition to removing dust and fume, also eliminates oxides of sulphur and, if recent recommendations by the Alkali Inspectors[2] are implemented, wet washing will also become compulsory at the smaller 'merchant' plants.

The gas is brought into contact with water by passing it through a tower containing a series of stoneware fillings over which the water cascades. Raschig rings in successive beds are sometimes employed, the rings being made of a ceramic material about ¼ in. thick, 2 in. long and 2 in. diam. and therefore presenting a very large number of wet surfaces to the gas.[5]

Washing appears to depend on the operation of a number of mechanisms:[6]

(a) Direct collision and absorption of particles by water droplets

(b) Diffusion of very small particles

Fig. 1   [After Stairmand and Kelsey[24]
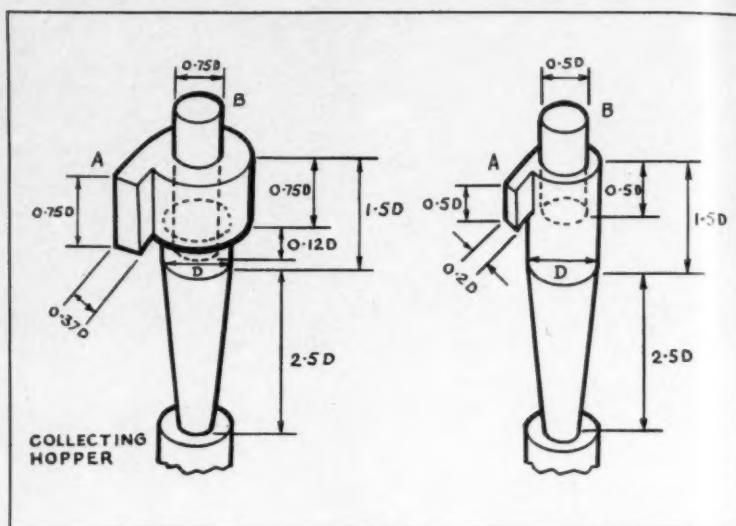
High throughput cyclone   High efficiency cyclone

(<0.5 micron) as well as gases into the droplets

(c) Condensation of water vapour on to particles which are thereby agglomerated

(d) Entrainment of particles by liquid droplets which have acquired electrostatic charge.

The efficiency of the washing can be considerably increased by spraying water into the gas and the process is then referred to as scrubbing. In Holmes towers, for example, where there is no internal packing, the gas is simply passed upwards through three separate spray and baffle zones. But in the Peabody high-velocity gas scrubber,[7] which has recently been applied to the cleaning of blast furnace gases, the tower has a more complex internal structure. It consists of a humidifying spray zone, a high-velocity agglomerating stage, an impingement cleaning stage and an entrainment stage in a single shell (Fig. 3).

The gas enters at the base of the scrubber and as it rises through the humidifying zone it is cooled and

saturated with a fine spray of water which dissolves some of the oxides of sulphur and strips the gas of its larger particles. It then flows upwards through the slotted plates which cause small particles to agglomerate and these are removed from the gas stream when they strike against the impingement baffle plates which are blanketed by water introduced from above. The gas then passes through an entrainment separator which removes the liquid carry-over, while the dust and grit are washed to the base of the tower and discharged in the form of a slurry.

Units capable of handling up to 200,000 cu.ft./min. of gas have been installed and the combination of dry cleaning with cyclones and wet cleaning with scrubbers results in a final dust content of the gas of less than 0.1 gr./cu.ft.

Electrostatic precipitation

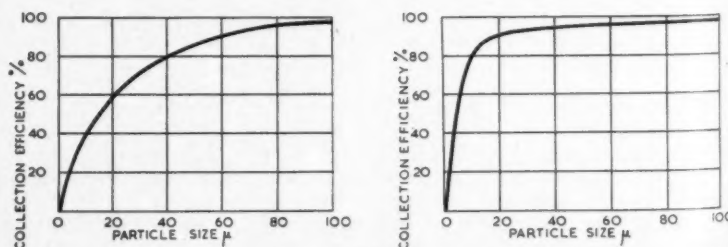At an increasing number of works electrostatic precipitators are now used to give the blast furnace gas a final

Fig. 2.   Grade efficiency curves   [After Stairmand and Kelsey[24]

High throughput cyclone (4 ft. diam.)   High efficiency cyclone (3 ft. 6 in. diam.)

cleaning before it is discharged into the atmosphere.

The principle of the method has been known for many years[8] and depends on the fact that, under the dual influence of a corona discharge and a lateral electric field, particles in a moving gas become ionised and then move to the electrode whose charge is opposite to that which has been induced on them.

If the ionising field is E_o and the lateral field is E, particles of radius r will move to the collecting electrode with a velocity U, given, as a first approximation, by

$$U = \frac{KEE_o r}{6\pi r_i}$$

where η is the viscosity of the gas and K is a number, varying between about 1.5 for particles with resistivities in the neighbourhood of 10^{10} Ωcm. and 3 for those with resistivities of about 10^4 Ωcm.

Using this expression it is possible to calculate the theoretical efficiency with which the precipitator will operate. But, in practice, complications are introduced by the effects of variables such as temperature, pressure, rate of gas flow, dimensions of the equipment, back discharge, particle re-entrainment, etc., with the consequence that practically every precipitator has to be specially designed for the particular plant in which it is to operate.

A number of firms in this country have supplied electrostatic precipitators for use on blast furnace gases; for illustrative purposes, Holmes - Elex precipitators may be described in a little more detail.[9]

They employ negative discharge electrodes which can be operated at voltages between 15 and 80 kV and which are frequently in the form of barbed wires to give a more uniform discharge and positive collecting electrodes. These are frequently in the form of flat plates fitted with weirs so that they can be continuously irrigated with water. The distance between the electrodes is usually between 8 and 10 in. and discharge currents of up to several hundred mA are employed.

During ionisation most of the particulate matter acquires a negative charge and therefore collects at the positive electrodes. However, a certain amount remains adhering to the negative discharge electrodes and this is removed in irrigated precipitators by periodic flushing with high-pressure water and in non-irrigated precipitators by mechanical rapping.

The particulate matter which col-

lects on the positive electrodes is likewise dislodged either by mechanical rapping or by irrigation with water. In the former case the frequency and severity of the rapping can be adjusted and the aim is to dislodge the collected material sufficiently frequently to prevent back discharge, but in a compact form so that it will fall rapidly into the hoppers below, thereby avoiding re-entrainment in the gas stream.

Collection efficiencies of over 95% on material down to 0.01 micron diam. are common, the gas leaving the precipitator generally containing less than 0.01 gr./cu.ft. of dust. A typical installation at the Bilston works of Stewarts & Lloyds is shown in Fig. 4.

Here the blast furnace gas passes first into a cyclone dust catcher and then into three scrubbing towers which connect with an irrigated electrostatic precipitator. The dust burden at the tower inlets is 2 to 3 gr./cu.ft., at their outlet about 0.2 gr./cu.ft. and the gas finally emitted from the precipitator contains between

Fig. 3. Peabody high-velocity gas scrubber showing spray headers, impingement baffles and water eliminator
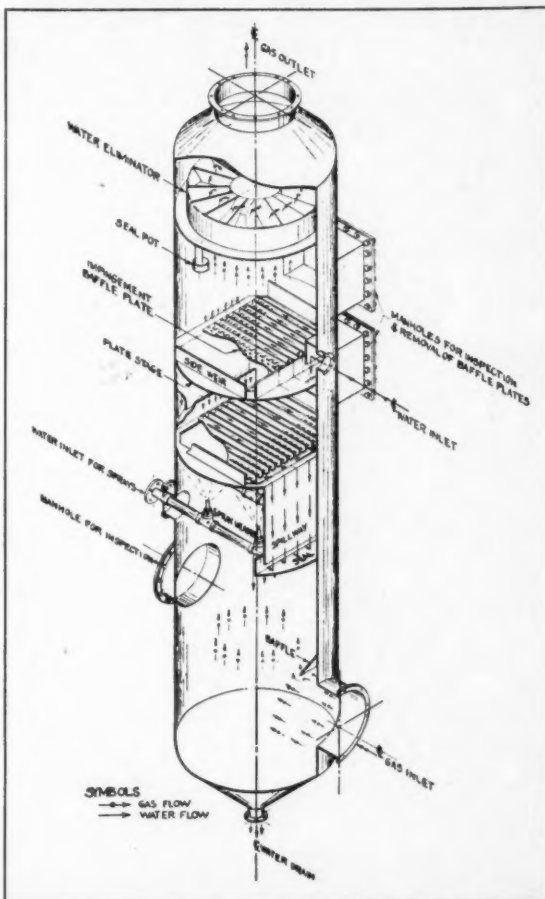
0.002 and 0.004 gr./cu.ft. Each of the three streams normally handles about 30,000 cu.ft./min. of gas and the whole installation operates at a pressure of between 5 and 12 p.s.i.

Steel-making

Dust and fume emission in steel-making can be conveniently discussed under the three headings of open-hearth furnaces, Bessemer converters and electric arc furnaces, even though the technique of oxygen lancing, which has been introduced in the last few years, to some extent cuts across this simple division.

While open-hearth furnaces are probably the main source of the dust and fume, since they account for about 80% of the steel production in England and Wales, Bessemer converters probably present the more intractable problem because of the extremely large volumes of hot and very dusty gas which they emit during the relatively short period of the blow. For example, a typical 200-ton open-hearth furnace produces about 25,000

cu.ft./min. of gas with a dust and fume content which averages between 0.05 and 0.5 gr./cu.ft.; on the other hand, a 25-ton Bessemer converter produces about 30,000 cu.ft./min. of gas at a temperature of about 1,500°C. during the 15-min. blow and the solids content of the gas is about 10 gr./cu.ft. Electric arc furnaces, which range in capacity from 1 to 80 tons, are probably the least obnoxious of the steel-making equipments as far as quantity of emission is concerned. Under normal circumstances this is intermediate between that of open-hearth furnaces and Bessemer converters, rising to a maximum of about 2 gr./cu.ft. of gas.

Oxygen lancing

The technique of oxygen lancing which was introduced on a pilot-plant scale at Linz and Donawitz in Austria in 1948[10] and which is now being used at an increasing number of plants in this country, has emphasised the need for efficient gas cleaning during steel-making.

In this process oxygen is blown through a metal lance either on to the surface or into the bulk of the molten metal. High local temperatures are produced, resulting in the evolution of substantially greater amounts of iron oxide fume than are produced in conventional steel-making. Thus an electric arc furnace producing 50 tons/hr. of steel evolves about 400 lb./hr. of iron oxide fume, but when oxygen lancing is used the fume rises to about 1,100 lb./hr. and represents a loss of about 1% on the weight of the original charge.

The fume is predominantly ($\sim$90%) iron oxide in a very fine state of sub-division, mixed with smaller amounts of SiO_2 ($\sim$2%), P_2O_5 ($\sim$3%), MnO_2 ($\sim$2%), etc., and appears highly coloured at concentrations above about 0.05 gr./cu.ft. Since most of the particles have diameters between 0.5 and 0.05 micron (Fig. 5), a high cleaning efficiency ($>$90%) in this range is required if the liberated gases are not to appear coloured and this restricts the cleaning equipment that can be used to three types: bag filters, venturi or other wet scrubbers and electrostatic precipitators.

Of these, bag filters have the advantage of a very high efficiency and moderate initial installation costs, although the bags need frequent replacement if used at temperatures above about 200°C.; venturi scrubbers and electrostatic precipitators, on the other hand, can both be operated at higher temperatures but are more

expensive to install, the former, in addition, requiring the availability of large amounts of water.

The decision which type of gas-cleaning equipment is to be installed at a particular works thus depends on a variety of factors, some technical like the type of furnace that is being used, the degree of cleaning that is required, the space that is available and the supplies of water and electricity that can be drawn upon; and others economic, like the initial capital cost of the installation, the subsequent running costs and the costs of maintenance and repair that will be required. All these factors must be taken into account in reaching a decision on the most suitable type for a particular works, and this explains why there is considerable diversity in the cleaning equipment that is employed in the steel industry at the present time.

Bag filtration

Considering bag filtration first, an experimental programme was recently concluded by British Oxygen Research & Development Ltd.[11] designed to assess the potentialities of the method, since, unlike the U.S. where it is now well established, bag filtration has only very recently been applied to steel-making in this country.

The source of the emission was 130 lb. of haematite iron at a temperature of 1,250° to 1,550°C., lanced with oxygen at the rate of 5 to 10 cu.ft./min. The emitted gas, whose temperature varied between ambient and 250°C., carried up to 17 gr./cu.ft. of dust and fume and was passed into a bag house consisting of 12 bags, 70 in. long and 5 in. diam. with a nominal filtering area of 84 sq.ft. Orlon and silicone-treated glass-fibre bags were used, the bags being shaken periodically to remove the deposit. Tests were made at various temperatures, rates of gas flow and fume and dust content.

Since then full-scale trials have been made at the Appleby Frodingham Steel Co.,[12, 13] using a modified Ajax tilting furnace and employing oxygen lancing at the rate of 950 cu.ft. oxygen/ton of metal. Here the cleaning plant consists of 15 compartments, each of 14 bags, 8½ in. diam. and 128 in. long with a total filtering area of 5,200 sq. ft. The plant handles about 10,000 cu.ft./min. of gas at a temperature of 200 to 240°C. containing up to 30 gr./cu.ft. of dust and fume. The initial tests were made using Orlon and Terylene bags, with cyclones for preliminary dust removal, but
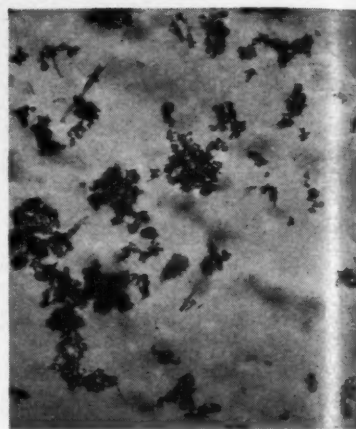
recently the cyclones were removed and the Orlon and Terylene replaced by bags of silicone-treated glass-fibre.

The conclusions to be drawn from these and other trials that have been made in the last few years[14] may be summarised as follows.

Bag filtration as applied to steel-making is highly efficient, removing from the gas over 95% of all material down to about 0.05 micron diam. and resulting in a discharge of less than 0.05 gr./cu.ft. of gas. Water is not involved, but power is consumed when the bags are cleaned by the periodic application of a reverse jet of air[15] or by mechanical shaking. The cost of the cleaning is moderate and, allowing for initial capital expenditure, power consumed, depreciation and maintenance, works out at between 0.03d. and 0.07d./1,000 cu.ft. of gas cleaned.[14, 16]

The main disadvantage of the method is that it is restricted to gases at a relatively low temperature. Thus bags of Orlon can be used only up to about 130°C., Terylene up to about 160°C., but silicone-treated glass-fibre bags operate satisfactorily up to about 240°C., one figure given for their life at this temperature being about a year.[11]

Although bag filtration has not so far been widely applied to steel-making in this country, it has potentialities and it is reasonable to predict that it will be increasingly employed in the future, particularly at works where space is not restricted, where costs are of importance and where cleaning is to be achieved in a single-stage process.

Wet scrubbing

Wet scrubbing has been applied at a number of works for removing

particulate matter and oxides of sulphur from the gases evolved during steel-making, and typical scrubbing equipment has already been described in the section on blast furnaces. The development of the Pease Anthony venturi scrubber in the past 10 or 15 years has increased the efficiency with which the smaller particles and the fume can be removed from the gas and this type of scrubber, which is therefore particularly applicable to steel-making, is now described in a little more detail.

It consists essentially of a metal tube, narrowing at one point to a diameter of 2½ in. and connected to a packed tower or centrifugal separator. Water is introduced radially into or just before the throat and is atomised by the fume-laden gas, which is being drawn at a high velocity of 200 to 400 ft./sec. through the tube. The particles of fume become wetted and, as the gas decelerates in the diverging section downstream from the throat, coalescence of fume and of the atomised droplets occurs, resulting in drops of sufficient size for them to be removed from the gas by centrifugal force or by impingement against baffles in the tower.

Venturi studies

A series of trials at the Redcar works of Dorman Long & Co. was recently undertaken in conjunction with the British Oxygen Co. and with the Power-Gas Corporation to study the mechanism of venturi scrubbing in greater detail.[17] The layout (Fig. 6) consisted of a 55-ton Kling-type ladle containing 30 tons of pig iron and 15 cwt. of limestone, which was lanced with oxygen at between 300 and 400 cu.ft./min. for a period of about 20 min. The gas—predominantly carbon monoxide at between 300° and 1,200°C.—was withdrawn via a close-fitting hood at the rate of about 250 cu.ft./min. and a portion was passed first through a spray cooler having four water nozzles in the roof and then into a venturi scrubber. The throat of the venturi was 2½ in. diam. and it was fitted with three sprays into which water was metered at 2 to 4 gal./min. at a pressure of about 5 p.s.i. The agglomerated fume was collected in a cyclone separator and the cleaned gas then passed through a fan to the atmosphere.

Measurements were made of the fume concentration in the gas before the precooler, before the venturi and in the final stack, of the inlet and outlet temperature of the venturi and of the pressure drop across it. In addition, analyses were made of the dried material collected by the precooler and by the Venturi scrubber and some typical results obtained during the trials are given in Tables 1 and 2. Since that time further developments have taken place in the design of venturi scrubbers. Chemical Construction Corp. now use a rectangular cross-section for throat sizes above 12 in., since this facilitates operation of the jets.

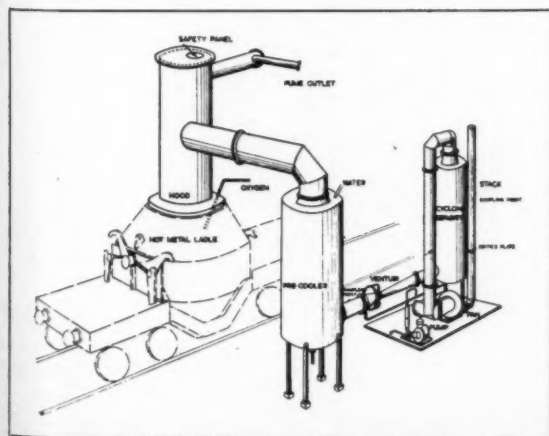Scrubbers handling up to 150,000 cu.ft./min. have been used on oxygen-lanced open-hearth furnaces[18] with an efficiency better than 95% even on particles below 0.5 micron diam., and the fume content of the gas is thereby reduced to less than 0.1 gr./cu.ft. The efficiency can be still further increased by operating at higher pressure drops, e.g. 30-40 in. w.g. across the venturi. In general, water consumption works out at about 3 gal./1,000 cu.ft. and the cost of the cleaning, allowing for capital expenditure and depreciation, at about 0.1d./1,000 cu.ft. of gas.[16]

'Rotoclone' hydrostatic precipitators

Rotoclone hydrostatic precipitators have also been introduced in recent years for gas cleaning in the steel industry and mention may be made of a Rotoclone type N which is now operating on a new 80-ton electric arc furnace in Scotland.[19]

It consists of an S-shaped impeller whose lower opening is partly submerged in water (Fig. 7). The gas is passed at a high velocity through the impeller and raises a heavy, turbulent sheet of water which is deflected by the lower blade through an angle of about 150° and is then projected downwards with great force by the upper blade. The entrained solids are thereby forced below the surface of the water in the Rotoclone tank, from which they are removed as a sludge, while the cleaned gas is passed through eliminators to remove the liquid carry-over and then to a stack. Efficiencies

Table I. Efficiency of fume removal

Experiment No.	Fume concentration, gr./cu.ft.			Efficiency, %		
	Before precooler	Before venturi	Final stack	Of precooler	Of P.A. scrubber	Combined
11	48.1	21.0	0.37	56	98.2	99.2
12	36.5	20.7	0.20	43	99.0	99.5
13	46.4	36.2	0.23	22	99.4	99.5
14	48.1	26.9	0.12	44	99.6	99.8
15	53.1	15.2	0.10	72	99.3	99.8
16	39.1	14.9	0.14	62	99.1	99.6

(By courtesy of the Power-Gas Corporation)

Table 2. Mean analysis of dried solids from aqueous effluents

Analysis	Precooler, mean %	Venturi scrubber, mean %
Total Fe ..	64.9	64.4
Fe oxides ..	89.4	88.7
SiO₂ ..	2.3	2.3
P₂O₅ ..	3.0	3.8
MnO ..	2.1	2.1
S (as SO₃) ..	1.5	1.6
Volatile material	1.3	1.5
Total ..	99.6	100.0

(By courtesy of the Power-Gas Corporation)

[Courtesy: Power-Gas Corp. Ltd.

Fig. 6. Test lay-out of 55-ton Kling-type ladle, lanced with oxygen
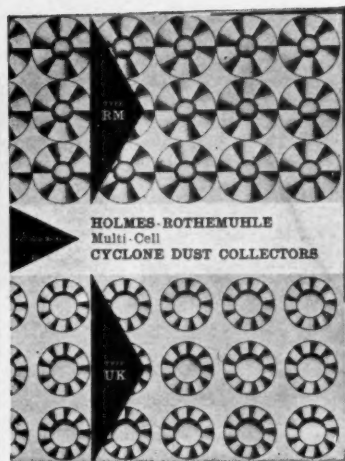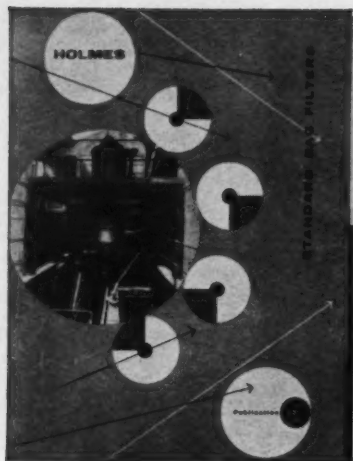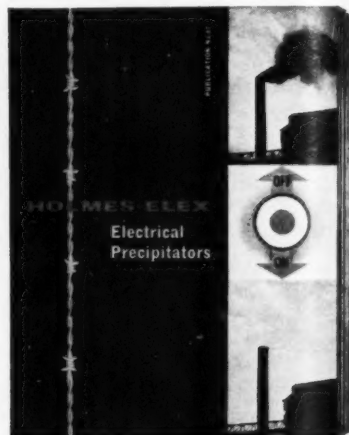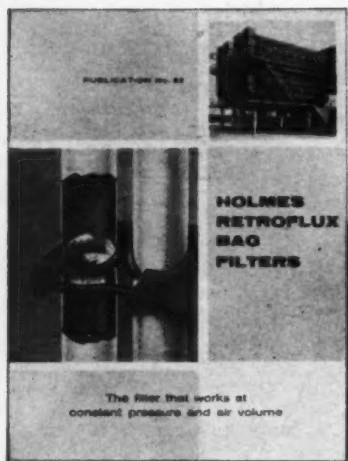
of between 65 and 81% have been achieved on gas containing 95% of material less than 0.5 micron diam.

Electrostatic precipitation

The last of the methods employed in the steel industry for cleaning the gases emitted by open-hearth, Bessemer and electric arc furnaces is electrostatic precipitation and, although the method has already been described earlier in this article, a few additional remarks of particular relevance to steel-making may be included appropriately at this point.

Electrostatic precipitation is particularly suited to the collection of the very fine particles of iron oxide in the fume from steel furnaces and, even when oxygen lancing has been used, is capable of reducing the solid material in the gas generally to less than 0.005 gr./cu.ft.

At temperatures up to about 400°C., no special corrosion problems arise, but in cases where the incoming gases are hotter than this, it is necessary to fabricate the electrodes in stainless steel or in other corrosion-resisting materials.[20]

Both dry and irrigated precipitators are in use and units handling many hundreds of thousands of cu.ft./min. of gas are common. The cost of the cleaning varies with the installation and with the temperature, volume and dustiness of the gas treated, but for dry precipitators it is generally in the region of 0.03d./1,000 cu.ft. of gas, rising for irrigated precipitators to about 0.07d./1,000 cu.ft.

Steam blowing

To complete the discussion on steel-making it should be mentioned that in recent years investigations have been made into the possibilities of reducing fume other than by the installation of gas-cleaning equipment, and the adoption of the technique of steam blowing has had good results in a number of cases.[21] It is particularly applicable when oxygen lancing is being employed and involves diluting the oxygen with up to 50% by volume of superheated steam. The steam dissociates into oxygen and hydrogen and apparently keeps the temperature of the metal below that needed to produce appreciable amounts of iron vapour at the points where reaction between the metal and the refining gases is occurring. However, close control is essential and, if excessive amounts of steam are employed, difficulties arise due to condensation of moisture.
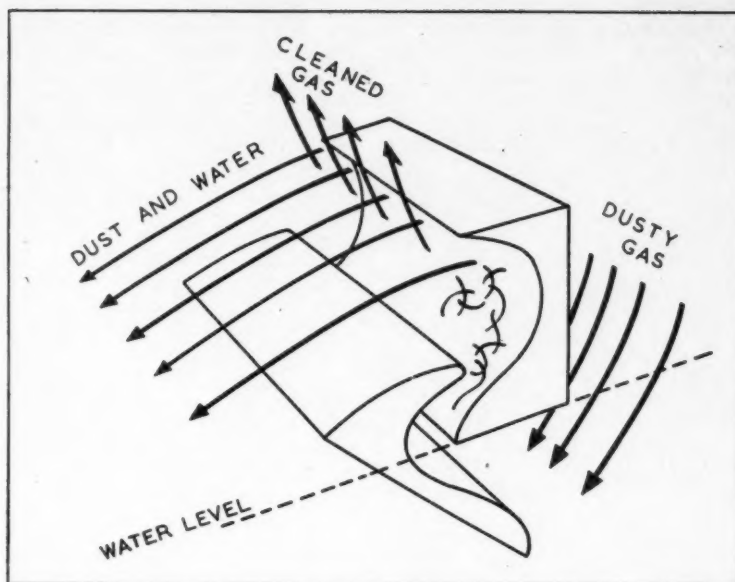

Fig. 7. 'Rotoclone' type N precipitator

Ancillary processes

We consider now some of the processes ancillary to the manufacture of iron and steel in which dust, smoke and fume are produced and in which, therefore, gas-cleaning problems arise.

Preteatment of ores

Many of the ores used by the industry require treatment before they are suitable for reduction in blast furnaces. Thus, while some ores are relatively dry and free flowing, others are wet and clayey and need to be dried. Drying is generally done in rotating drum-type dryers fired with hot gas from the blast furnaces and considerable amounts of dust and grit are produced.

With other ores it is necessary to subject them to calcination, the object being to increase the iron content by decomposition of carbonates and by evaporation of water and other volatile matter. This is particularly the case in home-mined ores where the iron content is generally less than 30%.

A bed of coal about 1-ft. thick is laid down on a suitable piece of land and is covered by a mixture of raw iron ore containing about $2\frac{1}{2}\%$ by weight of slack coal. The coal is ignited and, when combustion is complete after about three months, the ore is allowed to cool for a similar period and is then reclaimed. In this condition it is bone dry and extremely dusty.

The modern technique of sintering which, in addition to effecting all the objectives of calcination, converts the ore to the hard agglomerates necessary for good packing in the blast furnace, is being currently applied to over 10 million tons of ore a year and is a major source of dust, grit and oxides of sulphur.

The process consists essentially of drawing air through a burning bed of damp, crushed ore mixed with coke breeze, blast furnace flue deposits, pyrites cinder, etc., in which the moisture is regulated at about 10% and the carbon content at between 4 and 7%. The raw mix is delivered through hoppers on to endless moving strands of perforated pallets and, as each pallet comes into contact with jets of burning gas, the charge is ignited. Air is drawn downwards through the strand bed at such a rate that the mix is burnt through by the time the discharge end is reached and
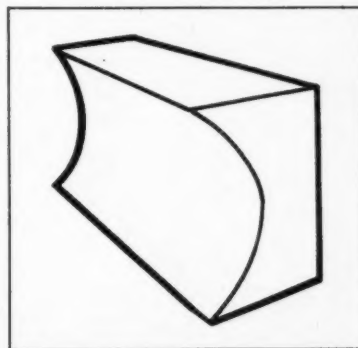

Fig. 8

the sinter is then quenched, broken up, screened and fed into the furnaces.

Large amounts of dust and grit are produced at all these stages and it has been proposed[2] that the emission permitted to the atmosphere should not exceed 0.1% of the weight of the sinter made.

For removal of the grit and larger particles of dust, coarse aerodynamic separators of the *Musgrave* type (Fig. 8) have been used with success. These consist of truncated metal cones, punched along their length by slots. The slots set up aerodynamic forces in the gas stream, causing the dust to concentrate down the centres of the cones, while permitting relatively dust-free gas to escape through the walls.

Successful trials have also been made with cellular dust collectors,[14, 22] and cleaning with cyclones, venturi scrubbers or with electrostatic precipitators has also been considered. But, in view of the immense volumes of gas involved, the cost of installation and running, these methods have not so far been adopted on other than a trial basis.

The melting of iron and steel in rotary and air furnaces for casting, rolling, forging, etc., calls for no special comment. But the use of cupolas and particularly hot-blast cupolas gives rise to a major problem.

The cupola consists essentially of a vertical shaft which is charged with a mixture of coke and the material to be melted. Air or preheated air is blown in at the base and the gases which emerge from the top of the cupola carry with them everything from coarse grit to a fine fume of iron oxide. More than 100,000 cu.ft. of gas can be evolved for every ton of metal melted, some of the larger cupolas having a throughput of 25 tons/hr. The burden of solid material varies between about 10 and 50 lb./ton of metal and at different stages in the

Fig. 9

process the temperature of the gas may rise to more than 1,000°C.

A variety of methods has been proposed for the separation of dust and fume from cupola gases.[23] They may be allowed to expand and then be subjected to sudden changes of direction by impingement against baffles. In this way up to 15% by weight of the solid material can be removed. By having the baffles blanketed with a fine spray of water (Fig. 9), the removal can be increased to over 30%.

Cyclones and multi-cyclones[24] are potentially suitable provided the cupola gases have been first cooled to below about 350°C. and other cleaning equipment that has been used, though so far, to a rather limited extent, includes bag filters, wet scrubbers and electrostatic precipitators.

Coke ovens

Coke ovens, on the other hand, present formidable problems and have for many years been a serious source of atmospheric pollution in steel-producing areas.

The modern coke oven consists of brick chambers about 40-ft. long, 12-ft. high and 18-in. wide which are erected in batteries of from 10 up to 80 in number. Coal of about $\frac{1}{8}$ in. diam. is charged into the ovens from above, the capacity of each oven being about 20 tons, and is carbonised by heating with coal gas. The coking period lasts about 20 hr., after which the hot coke is discharged by means of pushers, quenched with water and the whole cycle of operations is then repeated.

The major outstanding problems are associated with charging and discharging of the ovens.

Dust-free charging and discharging, however, can only be achieved by radical changes in design. Gas-cleaning appliances have not so far been used to any extent, although mention should be made of the employment of wet scrubbing as a means of removing dust and oxides of sulphur from the gaseous products of the carbonisation.

Conclusion

It would be misleading to conclude from the foregoing discussion that the problem of dust and fume emitted during the manufacture of iron and steel has been solved, or is indeed likely to be for many years. As the Alkali Inspectors state in their last annual report:[2] 'We are under no illusion as to the magnitude of the tasks facing us'. Nevertheless, a start has been made.

Viewing the industry as a whole, it

is apparent that, while there still remain a number of difficult technical problems to be solved, associated particularly with non-integrated blast furnaces, hot-blast cupolas, coke ovens and sintering plants, the outstanding difficulties are now rather of an economic and administrative nature.

How much, for example, can manufacturers be expected to contribute towards the cost of modernising their works and installing new gas-cleaning appliances? How long a period should be allowed for such conversions to be effected? Again, what levels of emission are realistic and attainable? Different processes produce vastly different quantities of dust and fume —some for many hours a day, others for only a few minutes every hour— and the siting of the plant and the local geography are of paramount importance in determining to what extent the emission will constitute an objectionable nuisance to surrounding areas.

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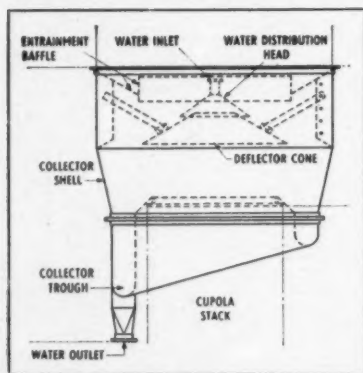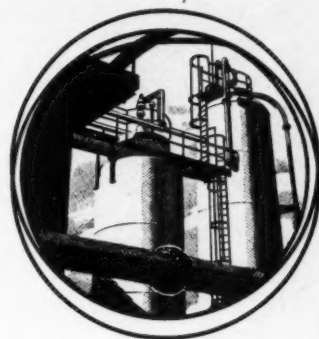[24] C. J. Stairmand and R. M. Kelsey, *Chem. & Ind.*, 1955, 1324.

Materials of Construction for Chemical Plant

MILD STEEL

By E. Ineson,* B.Sc., F.I.M.

The fourteenth article in our series 'Materials of Construction for Chemical Plant' deals with mild steel. Previous articles in this series have included PVC, lead, nickel, stainless steels, graphite, polyolefines, copper, timber, platinum, titanium, aluminium, reinforced plastics and cast iron. Undoubtedly mild steel is one of the most versatile materials available and it represents by far the greatest tonnage of metal used in the chemical industry, especially because the quality of mild-steel structures has improved steadily due to developments in steelmaking and fabrication.

MILD steel is undoubtedly one of the most versatile materials available to the plant constructor. It is a tenacious and very ductile metal which can be produced cheaply and of consistently good quality, and can be readily rolled into plates or forged, rolled, drawn or cast into shapes. The steel is easy to fabricate by welding and can be machined without difficulty. For these reasons mild steel must always be the first metal to be considered for chemical plant. In fact, mild steel is used in the chemical industry to a large extent for the structures of buildings, supports for plant vessels, boilers, conveyances and much of the machinery. In addition, many process vessels, tubes, etc., are still constructed of mild steel and this will continue so long as the life-to-cost ratio of mild steel compares favourably with that of more resistant materials.

The quality and reliability of mild-steel structures and vessels has been steadily improved by developments in methods of fabrication and parallel advances in steelmaking practice. Hence welded vessels have now almost completely superseded riveted ones. Also the inherent versatility of mild steels has been widened by minor modifications in the composition and treatment of steels and by the development of new or improved methods of protecting mild steel. The introduction of entirely new methods of steelmaking, involving the use of oxygen blowing, is likely to extend even further the value of mild steel for chemical plant construction.

Nature of mild steel

Mild steel is essentially an alloy of iron and carbon, having a maximum carbon content of about 0.25%. As produced commercially such an alloy contains varying amounts of other elements, some of which are beneficial and some not so. Elements such as silicon, manganese and aluminium are added as part of the steelmaking process and have a beneficial effect. Others such as sulphur and phosphorus, which cannot be removed easily, occur in the raw materials and may be deleterious if present in too large amounts (more than 0.05%). Certain elements such as nickel, chromium, molybdenum, copper, boron, tin, arsenic, etc., may find their way into the steel in trace amounts from scrap used in manufacturing the steel, but for special purposes small amounts of the first four named elements may be deliberately added.

Mild steel may be made in either an acid refractory-lined furnace (silica) or a basic refractory-lined furnace (dolomite, magnesia) and, depending upon the degree of deoxidation, it may be a rimmed steel, a capped steel, a semi-killed steel or a killed steel. Originally all the best-quality steels were produced in the acid open-hearth furnace from high-grade materials, but over the past 20 years improvements in production techniques have made it possible to produce equally good-quality steel in the basic open-hearth furnace from lower-grade materials, *e.g.* high-phosphorus ores. Rimmed steels are characterised by a pronounced lack of chemical homogeneity but they possess a soft, low-carbon iron surface which makes them particularly suitable for deep drawing or deep pressing and for forgings requiring especially good smooth surfaces. Capped steels result from an interruption of the rimming action by freezing the ingot head, and their properties are similar to those of

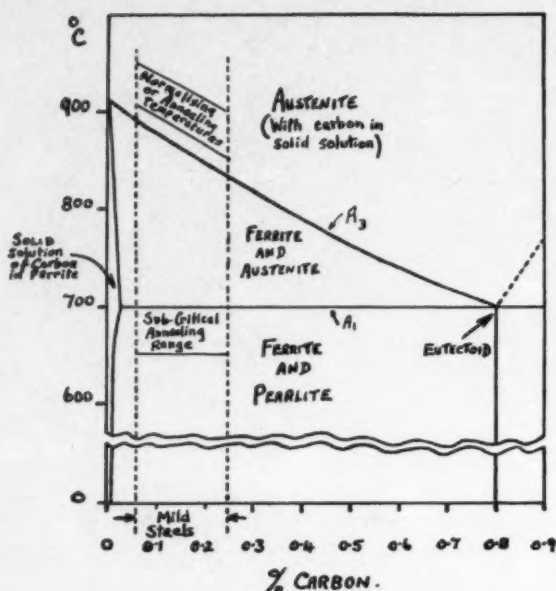*Metallurgy Division, British Iron and Steel Research Association, Sheffield.

Fig. 1. Phase diagram temperature v.s. carbon content for steels

The diagram axes: °C (vertical, marked 900, 800, 700, 600, 0), % CARBON (horizontal, marked 0, 0·1, 0·2, 0·3, 0·4, 0·5, 0·6, 0·7, 0·8, 0·9). Labels: Normalising or annealing temperatures; AUSTENITE (with carbon in solid solution); A_3; FERRITE AND AUSTENITE; Solid solution of Carbon in Ferrite; Sub-Critical Annealing Range; A_1; FERRITE AND PEARLITE; EUTECTOID; Mild Steels.

show the effect of normalising and 'renormalising' an annealed steel. A compromise is usually adopted for hot-rolled mild-steel products. By careful adjustment of the temperature at which hot working is finished, followed by cooling in air, it is possible to approach close to the normalised condition. A great deal of mild steel is used in the 'as-rolled' condition.

Formerly it was the custom to construct mild-steel structures and vessels by riveting. This is a cheap and rapid method, but on the other hand it is not suitable for thick plates and the riveted seams provide sources of corrosion and leakage. Also riveted constructions are somewhat heavier than similar welded ones. To a large extent, therefore, riveting has been replaced by welding which, though more expensive, produces a more

rimmed steels, but they have a more uniform internal structure and are somewhat more expensive than rimmed steel. Semi-killed steels represent an intermediate deoxidation stage between rimming and killing and are probably the most economical form of mild steel. A killed steel is fully deoxidised with silicon or aluminium and is characterised by minimum chemical segregation, maximum soundness and good uniform mechanical properties. This is the most expensive form of mild steel.

The fundamental constitution of mild steel is not greatly affected by the method of steelmaking or by the presence or absence of incidentally occurring elements. It owes its properties mainly to the existence of two allotropic forms of iron and to variations in carbon content. Above about 910°C. iron exists as a face-centred cubic crystal form known as austenite which is capable of taking an appreciable amount of carbon into solid solution. Below 910°C. the iron transforms to a body-centred cubic crystal known as ferrite which has only a very limited capacity for dissolving carbon. The different phases thus provided form the basis for the heat treatment of steel and are depicted in Fig. 1. It may be seen that above a critical temperature of 850° to 900°C., depending upon carbon content, mild steel is wholly austenitic with all the carbon in solid solution. Increasing carbon content depresses the critical temperature (A_3) above which austenite is stable. On cooling below the

critical temperature (A_3) the austenite begins to transform to ferrite and mixtures of ferrite and austenite co-exist between the A_3 temperature and the lower critical temperature of about 700°C. (A_1). During this stage of cooling, the majority of the carbon remains in solid solution in the surviving austenite so that on reaching 700°C. it contains about 0.8% carbon. On further cooling below 700°C. the saturated solution of carbon in austenite transforms to an intimate eutectoid mixture consisting of alternate plates of ferrite and iron carbide (Fe_3C), which has been called pearlite because of its iridescent appearance. Fig. 2 shows the microstructure of a mild steel which has been cooled slowly in a furnace from 900°C. It consists of comparatively large crystals or grains of ferrite interspersed with grains of fairly coarse lamellar pearlite and is typical of a fully annealed mild steel.

Mild steel in the annealed condition is in its softest and most ductile condition and this is of advantage for some cold-working operations. More generally, however, a somewhat harder and stronger material is required and this can be achieved by refining the grain size. A coarse-grained mild steel can be refined by reheating it to just above the upper critical temperature and cooling it rapidly in air. This is done in practice when the best optimum properties are required in a steel and the cost of reheating can be justified. The treatment is known as 'normalising' and Figs. 3 and 4
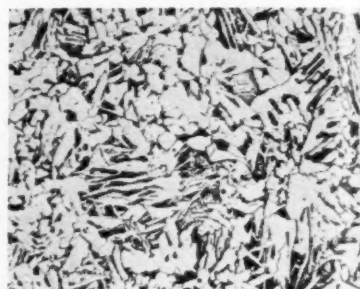

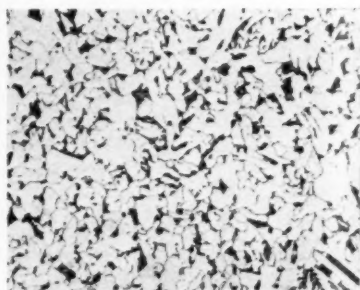Fig. 2. Mild steel (0.17%C) slowly cooled in furnace from 900°C. (annealed)   (× 500)

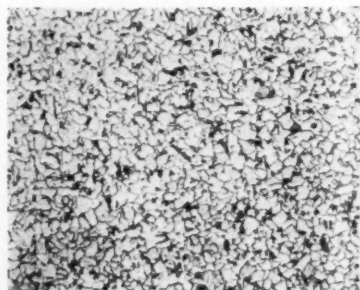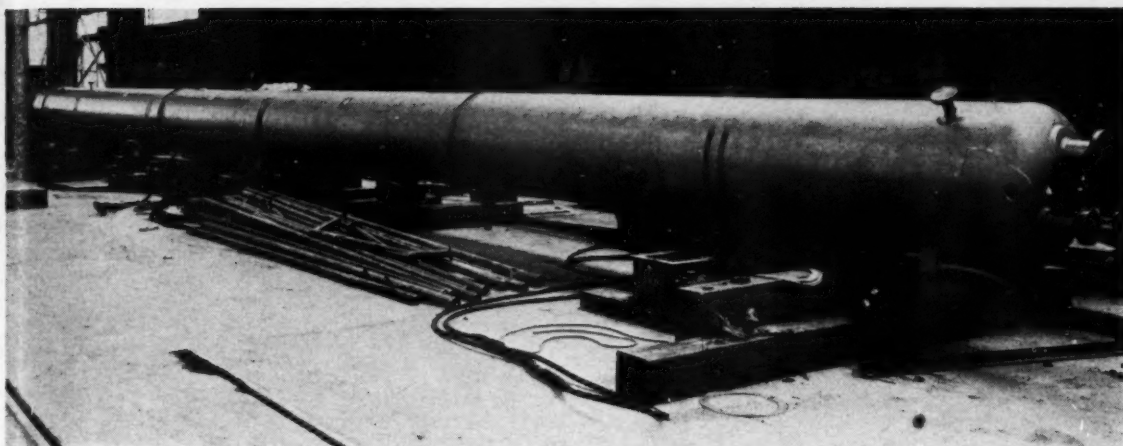Fig. 3. As Fig. 2, reheated to 910°C. and cooled in air (normalised)   (× 500)

Fig. 4. As Fig. 3, after repeated normalising treatment   (× 500)

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100-ft. column for the olefine plant of I.C.I. Wilton in the shops of Head Wrightson Teesdale Ltd.

satisfactory and reliable product which is easier to maintain.

Mechanical and physical properties

The properties of mild steels vary somewhat with composition and method of manufacture, and advantage is taken of this in practice to establish different grades of mild steel which are particularly suited to certain purposes. The mechanical properties required for each grade of wrought and cast mild steel used in chemical plant are specified in appropriate British Standards such as B.S. 1500, B.S. 1501-1506 and B.S. 1510 and it is not proposed to refer to them in detail here. A few typical properties are indicated below.

A dead-soft mild steel having a carbon content less than 0.12% and a manganese content up to 0.5% has a tensile strength of about 24 tons/sq.in., a yield strength of 12 tons/sq.in. and an elongation of 25%. Such a steel is especially suitable for deep pressings and solid-drawn tubes and it is also very easily welded.

A normal wrought mild steel containing up to a maximum of 0.25% carbon and about 0.7% manganese has a tensile strength in the range 26 to 32 tons/sq.in., a yield strength of 13.5 to 15 tons/sq.in., and an elongation of 20 to 23%. These steels are usually supplied in the 'as-rolled' condition, but thin plates and sections may require annealing to soften them. Heavy plates, say over 2 in. thick, may be normalised to refine the structure. This quality of steel is readily weldable and comprises the bulk of material used in the pressure vessel industry.

For higher working pressures, various so-called high-tensile mild steels are available with tensile strengths in the region of 34 to 44 tons/sq.in. and yield strengths of 19 to 27 tons/sq.in. This type of steel has a high limit of proportionality which, combined with good ductility, is an advantage in the design of high-pressure vessels. Such steels may contain up to 1.7% manganese and, in some cases, small additions of nickel, chromium and molybdenum are added but, provided that the carbon content does not exceed about 0.25%, the welding properties are very good. Such materials are particularly suitable for vacuum vessels and vessels subjected to high external pressure.

More recently a new high-strength weldable steel containing molybdenum and boron with comparatively low carbon content has become available. In the normalised condition this steel has a tensile strength greater than 40 tons/sq.in. and a yield strength in the region of 35 tons/sq.in. and possesses substantially better elevated temperature properties than the simpler mild steel. This material offers an unusual combination of properties which will undoubtedly find an important field of application in the chemical industry.

Mild steels have a limited use at elevated temperatures and the success or otherwise of such service will depend very much on the environment. They have, however, been used successfully for steam plant working up to a maximum temperature of about 450°C. and, under these conditions, they will operate at reasonably high stresses.

Low-temperature properties

Some chemical processes are carried on at low temperatures, and storage of liquefied gases at low temperatures is growing in importance. Mild steel retains its tensile strength and tensile ductility down to about –100°C., but unless suitable precautions are taken it is very prone to becoming notch brittle at sub-zero temperatures. This condition is influenced very much by the composition, method of steel-making, grain size, condition of heat treatment and degree of cold work. For good low-temperature properties it is important that the steel should have a ratio of manganese to carbon content not less than three to one, and the steel should be fully killed, preferably with aluminium, to produce a fine-grained steel. Notches must be eliminated from the design of the vessel and the finished vessel should be stress relieved at 650° to 700°C. in order to remove the effects of cold work. The best condition of heat treatment for good sub-zero properties is hardened and tempered, but this is often not practicable and normalising and tempering is the next best alternative. Full annealing will tend to give poor impact strength at low temperatures. Provided that attention is given to all the points mentioned, mild steel can safely be used at temperatures down to about –50°C., at which temperature it should have a notched bar impact strength of about 15 to 20 ft.lb.

Typical physical properties for three grades of mild steel are shown in Table 1.

Mild steel is a useful magnetic material having a maximum permeability of 2,000, a saturation induction of 21,200 gauss and a coercive force of 1.8 oersteds. The maximum permeability and coercive force can be improved considerably by lowering the

carbon and nitrogen content and other trace element contents.

Corrosion characteristics

In a chemical plant, steel is required to withstand an unusually wide variety of corrosion attacks, depending on its particular location. Thus, for instance, it is subjected to corrosion from the soil, the atmosphere (often heavily polluted), water of varying chemical content, various gases, and from the various reagents and products being processed. The corrosion may take the form of direct chemical attack or of electro-chemical attack, but it is probable that most forms of corrosion attack of steel are electro-chemical in nature. Steel or iron is near the electro-positive end of the galvanic series of metals and, in fact, only cadmium, aluminium, zinc and magnesium of the more common metals are anodic to mild steel. Association with metals such as lead, tin, nickel, copper, brass, stainless steel, etc., which are cathodic to mild steel, could lead to accelerated corrosion of the mild steel. Even within the mild steel itself, local inhomogeneities such as non-metallic inclusions, local composition variations, or localised stressing can provide small electrolytic cells at which corrosion will occur. The corrosion will generally only proceed actively if both oxygen and moisture are present.

Soil corrosion

Corrosion in soil is particularly severe in waterlogged clay and in made-up ground containing ashes or clinker. Perforation of a buried steel pipe can occur within a year, and lives of from five to ten years are not uncommon. Replacement of pipes after such short periods is costly. In wet, heavy soils which prevent access of air, the oxygen required for corrosion is derived from the reduction by bacteria of sulphates present in the soil, and the rust so formed contains iron sulphide. It has been found from examination of steel piles that undisturbed soil tends to be less corrosive than disturbed soil because over the years it has been depleted of oxygen by organic matter present in the soil. Soil corrosion can be prevented by the provision of a heavy bituminous coating on the steel, reinforced with hessian or glass-fibre. Further valuable protection may be obtained by the cathodic action of a magnesium couple.

Atmospheric corrosion

This is perhaps one of the most prevalent forms of corrosion to which

Table I. Physical constants for mild steels (after Dr. E. Griffiths)

		Dead soft mild steel (B.O.H. rimming)	Dead soft mild steel (B.O.H. killed)	Normal mild steel (B.O.H.)
Carbon content, %		0.06	0.08	0.23
Density, at 15°C., g./cc...		7.871	7.856	7.859
Specific heat, g.cal./g./°C.	50 to 100°C.	0.115	0.115	0.116
	250 to 300°C.	0.132	0.133	0.133
Thermal expansion, 50 to 100°C.		12.38	11.74	11.92
Coefficients	250 to 300°C.	14.40	14.72	14.10
Thermal conductivity, g.cal./cm./sec./°C.	0°C.	0.156	0.142	0.124
	100°C.	0.144	0.138	0.122
	300°C.	0.122	0.118	0.106
Electrical resistivity, microhm cm.	20°C.	13.0	14.2	16.9
	100°C.	17.8	19.0	21.9
	300°C.	34.1	35.2	38.1

Table 2. Conditions permitting the satisfactory use of mild steel (Extracted from 'A.S.M. Metals Handbook', 8th Edition)

Service	Pressure, p.s.i.	Temperature, °C.
Acetone ..	150	370
Acetylene	150	150
Alcohol	300	200
Ammonia	600	500
Benzene (Cu-free steel)	470	450
Calcium chloride brine	50	100
Carbon disulphide	300	500
Carbon tetrachloride (Cu-free steel) ..	300	500
Caustic (under 5%) (Cu-free steel)	400	120
Caustic (0 to 10%)	150	180
Caustic (11 to 50%) (stress-relieved welds) ..	150	120
Chlorine gas	50	150
Chloroform (Cu-free steel)	300	500
Hydrogen	150	450
Hydrogen (Cu-free steel)	600	500
HCl gas (Cu-free steel)	150	500
Sodium	150	500
Sodium cyanide solution (Cu-free steel)	25	100
Sodium polysulphide solution	150	500
Xylene	75	150

mild steel is subjected in the chemical industry and yet it is often the most neglected. Serious cases are associated with the formation and retention of scaly rust on the steel surface which retains moisture and accelerates the rate of rusting. The best method of protecting structural steelwork against atmospheric corrosion is by means of paint alone or in conjunction with a metal coating. To obtain satisfactory protection of mild steel by painting, it

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The material of construction for chemical plant which will be discussed in next month's issue of CHEMICAL & PROCESS ENGINEERING will be

SILVER

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is essential to pay considerable attention to three factors, *i.e.* surface preparation, choice of painting scheme and painting procedure. The first of these is by far the most important. A total thickness of paint of not less than 0.005 in. should be aimed at, comprising three to four coats all put on in warm and dry atmospheric conditions. A faulty painting scheme may fail within a year, whereas a good one can last for ten years or more.

The addition of up to 0.6% copper to mild steel assists its resistance to atmospheric corrosion, and a higher phosphorus content is also beneficial, but it is doubtful whether these additions are worth while in a properly painted structure.

Water corrosion

Corrosion of mild steel by either natural or industrial waters can have serious consequences in chemical works. Differential aeration of the water with oxygen is probably one of

the most serious causes of corrosion, giving rise to water-line attack, crevice corrosion and certain forms of deposit attack. Dissolved hydrogen sulphide is also most objectionable since it can lead to severe corrosion even in the absence of oxygen. Free carbon dioxide is less serious, but it can be troublesome in a boiler by contaminating the steam and eventually re-dissolving in the condensate. This becomes acidic and can cause severe corrosion of condensate lines. The acidity or alkalinity of the water is important and generally iron and steel are less attacked by alkaline waters. For this reason it is often useful to raise the pH of corrosive water by adding an alkali, such as tri-sodium phosphate. Treatment with caustic soda to a pH of about 8.5 is also practised. Too much caustic addition to the water can lead to so-called caustic embrittlement of mild steel, which could be better named caustic cracking. This usually occurs where non-uniform stress distribution exists in the steel and where a relatively high concentration of caustic is available. It has been mainly found in riveted boilers, but it can occur in welded vessels that are not properly stress relieved.

Chemical processing

Many process vessels are made in mild steel, and corrosion does take place, but if this is sufficiently slow the life-to-cost ratio of mild steel may justify the continued use of mild steel. In some cases, however, where contamination of the product with corrosion products cannot be accepted, the surface may be protected by paint, metal spraying or by a protective resin lining. This type of protection is not satisfactory for really severe corrosive conditions because it is usually not possible to obtain a perfect coating. Some processes involve pressure and generally the pressure vessels require to be manufactured in steel because of its superior strength. In these and other cases where cheapness, strength and ease of fabrication are desirable, allied to extreme corrosion resistance, it is possible to use 'clad' steels. These consist of a backing of mild steel with a facing of nickel, nickel alloy, stainless steel or other corrosion-resisting alloy amounting to 10 to 20% of the total thickness. Clad steels require only slight modifications to normal cutting and welding techniques for mild steel and can not only reduce the cost of a new installation but may also allow more extensive plant development.

Cold rolling a 4-in. steel plate in a 3,000-ton vertical plate bending machine at the works of Head Wrightson Teesdale Ltd.

Other types of resistant coating of mild steel such as rubber or ebonite lining, enamelling, electro-deposited metal coatings, diffusion coatings of metals, etc., may also be used in suitable circumstances.

Mild steel alone is used extensively in the handling of acids and typical examples of its behaviour are referred to below.

Sulphuric acid can be handled by mild steel in concentrations from 70 to 78% and greater than 101%; 100% acid, particularly above 50° to 80°C., and dilute sulphuric acid, attack mild steel rapidly.

Hydrofluoric acid rapidly corrodes mild steel at concentrations below 63%, but stronger acids are resisted. The safe limit is probably 70%. Killed steels have been found to be 10% more resistant than semi-killed steels.

Nitric acid in dilute form and in concentrations up to 65% dissolves mild steel rapidly at room temperature. Above 63% mild steel becomes passive and the corrosion rate drops to a low value. The effect depends upon temperature and at 77°C. the concentration must be 90% whilst above 88°C. passivity cannot be achieved.

Hydrochloric acid and hydrogen sulphide corrode mild steel rapidly under most conditions.

Other substances which may safely be handled by mild steel under suitable conditions of temperature and pressure are listed in Table 2.

Hydrogen embrittlement of mild steel is a serious consideration in refinery applications. The establishment of local concentrations of molecular hydrogen at high pressure inside the steel can readily cause it to crack or blister.

Conclusion

In assessing the suitability of a material for chemical plant construction, careful consideration must be given not only to the particular conditions of service but also to the forms in which the material is available and to the ease with which it may be formed or fabricated. Maintenance costs and the need to avoid a shutdown must also be borne in mind. In considering all these factors it will be found that in many cases the extra cost of specially resistant steels or alloys with increased difficulties in construction cannot be justified, and mild steel will continue to be used. Where mild steel alone cannot withstand a particular corrosive attack there seems to be a very good future for mild steels clad or coated with one or other of the specially resistant materials.

Cost Indices—1960

To facilitate comparisons, a number of significant indices have been brought to the same starting point as the CPE construction cost index for January 1960.

Curve 1 for the construction cost index makes a pleasant picture, showing, as it does, a rise of less than 1% throughout the year. During the same time the cost of materials of construction has stayed almost unchanged while wages (curve 2) and process equipment (curve 3) show rises of about 1¾%. It is most interesting and gratifying to note that construction costs have been able to absorb these increases in labour and equipment costs without a corresponding increase.

When one examines the costs of materials which contribute to the costs of fabricated equipment, it is found that, while carbon steel prices have altered very little during the year, non-ferrous metal prices have fallen to about seven-eighths of their value at the beginning of the year. Since the latter are used only in more expensive equipment items, the effect of this fall must be less when combined with other relatively steady costs than curve 4 would at first sight suggest. Rather surprisingly, the equipment cost index seems to follow the wages curve and ignore the effect of declining costs of non-ferrous metals. That we are justifiably surprised is perhaps shown by the downward trend of the Marshall and Stevens index (curve 5) for chemical plant equipment in the United States.
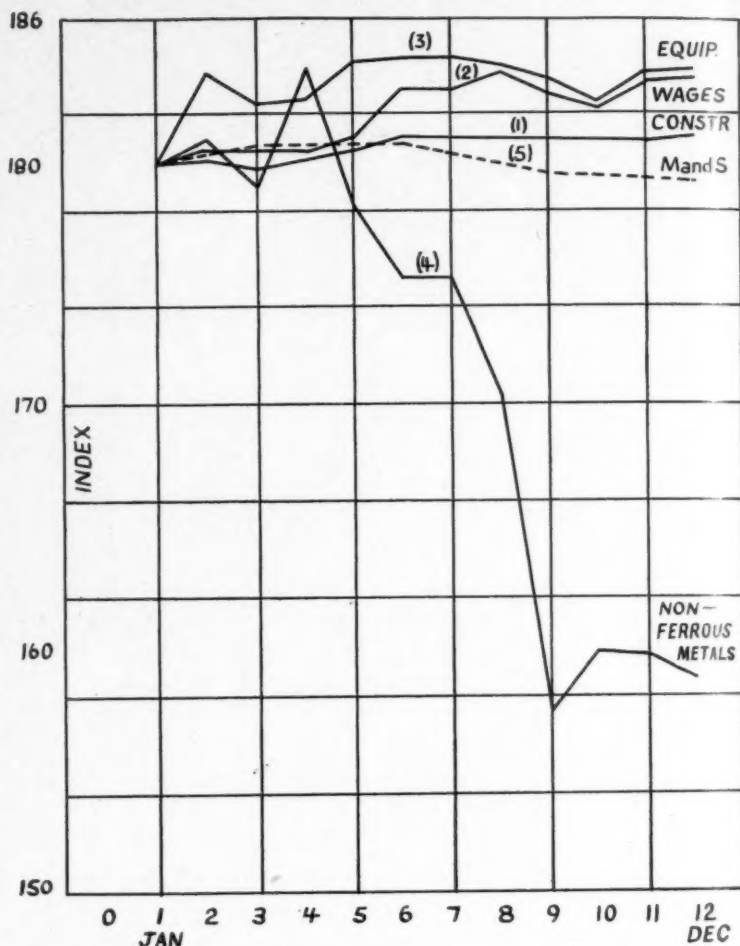
Summary of indices for 1960 (1949 = 100)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
CPE Construction Cost	180.1	180.2	179.7	180.2	181.6	181.2	181.1	181.1	181.1	181.0	181.0	181.2
CPE Equipment Cost	166.6	170.0	168.9	169.0	170.4	170.6	170.6	170.2	169.7	169.0	169.8	169.9

Impulse valve

A special impulse valve designed for the discharge of precipitates such as sludges, pulps and crystal muds is made by Giovanola Frères S.A. Owing to its periodic opening and closing, the valve never clogs; it is equipped with its own pneumatic control apparatus.

Its principle of construction is as follows: a mushroom valve head is lifted at regular intervals to a height of 3 cm., giving a large free area for the passage of flow. The resulting powerful current through the valve washes away any crusts formed on the valve head by sediments which are broken up by the lifting of the valve. Flow through the valve is practically continuous, the frequency and duration of the opening and closing of the valve being an adjustable variable.

The valve head, spindle and valve seat are made of 18/8/Mo stainless steel. The valve body can be a casting made of either cast iron or of stainless steel. Some typical applications for which this valve is suitable is for feed dosage to centrifugal machines, tapping sludge from decantation tanks and draining mother liquors.

Personal Paragraphs

Dr. R. A. Gregory

Dr. A. W. Henderson

★ **Mr. Michael J. S. Clapham,** who has been chairman of I.C.I. Metals Division since January 1, 1960, has been appointed a director of I.C.I. He is to be an overseas director *vice* **Dr. J. S. Gourlay,** who is to be Group A director (responsible for Alkali & General Chemicals Divisions). Mr. Clapham is a director of Pyrotenax Ltd., Yorkshire Imperial Metals Ltd. and Imperial Aluminium Co. Ltd. He is chairman of the Non-Ferrous Wrought Metals Export Group and a vice-president of the British Non-Ferrous Metals Federation.

★ **Mr. Harold Smith,** who has been chairman of I.C.I. General Chemicals Division for the past two years, has been appointed a director of I.C.I. He will take over as technical director from Dr. R. Beeching on June 1 when Dr. Beeching becomes chairman of

Mr. H. Smith

Mr. M. J. S. Clapham

the new British Transport board. Mr. Smith has been chairman of Plant Protection Ltd. and a member of the board of the I.C.I. subsidiary company in America, Arnold Hoffman Inc.

★ **Mr. D. Emmott** has joined the technical division of Process Plant Contractors (Campbell) Ltd. as a senior design chemical engineer. Mr. Emmott was previously with British Titan Products Co. Ltd. at Billingham, where he was employed as plant manager.

★ **Sir Arthur Vere Harvey,** C.B.E., has been appointed to the board of Ciba Ltd., Basle. This is the first time that an executive of the Ciba group of companies in Great Britain has been made a director of the parent company and may be considered as an indication of the importance attached by the Swiss board to the role of the British companies in this international chemical group.

★ **Prof. D. M. Newitt,** F.R.S., will retire as head of the department of chemical engineering and chemical technology, Imperial College, in September and has been appointed senior research fellow at the college. He will be succeeded by **Prof. A. R. Ubbelohde,** F.R.S., at present Professor of Thermodynamics, who is also director of the Salters Institute for Industrial Chemistry.

★ **Mr. W. F. Gerrard** has resigned from his position as technical manager of the Liverpool Borax Co. Ltd. (Feedwater Specialists Co. division) and has been appointed managing director of the Atlantic Water Treatment Co. Ltd., 87-89 Victoria Street, Liverpool 1.

★ **Mr. R. P. Newman** has been appointed head of the members' service department of the British Welding Research Association in succession to **Mr. P. H. R. Lane,** who has been appointed director of research of the Drop Forging Association. **Mr. T. R. Gurney** will succeed Mr. Newman in charge of fatigue researches at the British Welding Association.

★ It has been announced that **Mr. W. E. K. Piercy,** development director of Albright & Wilson Ltd., has been appointed to the board of W. J. Bush & Co. Ltd.

★ **Mr. G. V. Taylor,** works manager at the Newport factory of Monsanto Chemicals Ltd., is retiring on June 1. He will be succeeded by **Mr. A. C. W. Pemberton,** general superintendent of technical services at Monsanto's Fawley factory.

★ The Institution of Works Managers has elected as vice-presidents of the Institution: **Mr. E. J. Hunter,** chairman of Swan, Hunter & Wigham Richardson Ltd., **Mr. J. R. Edwards,** managing director of Pressed Steel Co., and the **Hon. Geoffrey Rootes,** deputy chairman and managing director of Humber Ltd., who have accepted their offices.

★ The medal of the Society of Chemical Industry has been awarded for 1961 to **Sir Cyril Hinshelwood,** O.M., past-president of the Royal Society and Nobel Laureate for chemistry. The medal, a senior award of the society, is presented every two years for conspicuous services to applied chemistry.

★ **Dr. R. A. Gregory** recently resigned as joint managing director of Midland Silicones Ltd. in order to take up a new appointment with the Albright & Wilson group as head of the department of inter-company planning.

★ The Plessey Co. Ltd. announces the appointment of **Dr. A. W. Henderson** as chief chemist/metallurgist. Dr. Henderson will work at the company's Ilford headquarters and was previously with Ciba (A.R.L.) Ltd. and Ferranti Ltd.

★ Following the appointment of **Dr. R. Spence** as deputy director of the Atomic Energy Research Establishment at Harwell, **Dr. W. Wild** has been appointed head of the chemistry division. He has responsibility for the scientific work of three branches: chemical processing and reactor chemistry; radiation chemistry and solid-state chemistry; and radiochemistry.

★ Laporte Industries Ltd. announce that **Mr. G. F. Sommerville,** manager of the Baronet Works, Warrington, has been appointed a director of Laporte Chemicals Ltd. He joined the company in January 1957 in connection with the commissioning of the organic chemical process for the manufacture of hydrogen peroxide.

★ The Institution of Mechanical Engineers have awarded the 1960 James Clayton Prize to **Dr. W. Ker Wilson** for his contributions to mechanical engineering science by way of theoretical investigation leading to practical solutions to many outstanding problems. This prize, drawn from the Clayton Trust Fund, is awarded annually to a member or members of the Institution who in the opinion of the council contribute most in the year to modern engineering science.

★ Two new directors have been appointed to the board of R. Jenkins & Co. Ltd., Rotherham. **Mr. Harold T. Jenkins** is to be technical director and **Mr. J. S. Waring** production director.

Equivalent Diameters of Heat Exchanger Tube Bundles

By D. S. Davis*
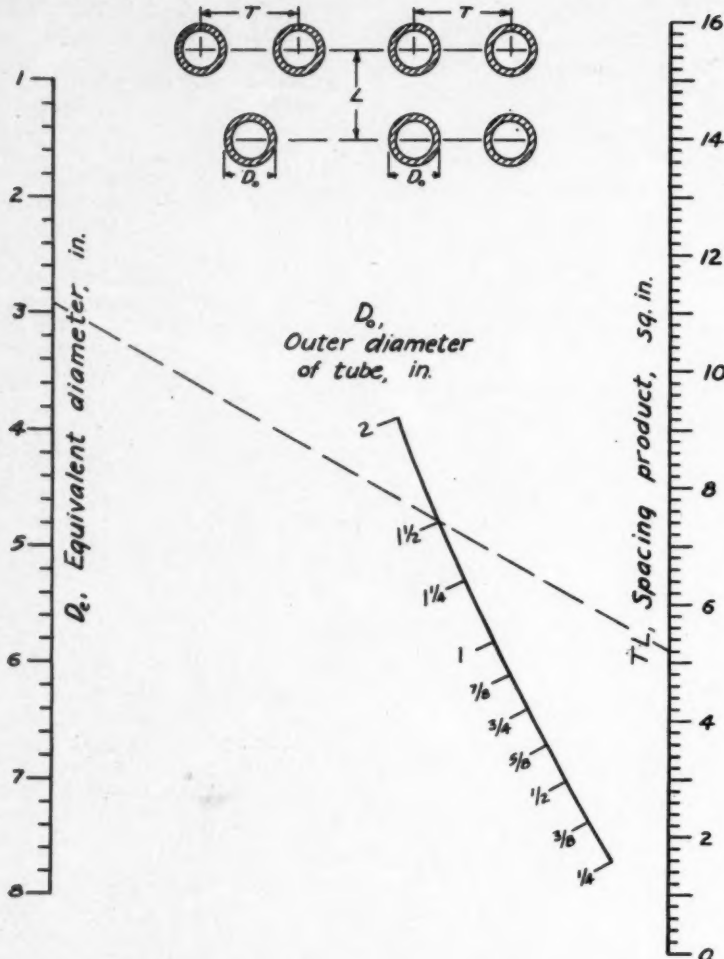
In making heat-transfer calculations when bundles of heat-exchanger tubes are concerned, the equivalent diameters may be calculated by means of the equation

$$D_e = \frac{4TL}{\pi D_o} - D_o$$

where D_e = equivalent diameter in inches, T and L are spacings on centres, in inches (see diagram), and D_o = outer diameter of the tubes, in inches.

This equation, of the recurrent variable type, is easily solved through use of the accompanying nomograph,

which was constructed in accordance with methods previously described.[1]

The broken index line on the chart covers the case where the spacings of $1\frac{1}{2}$-in. tubes T and L are 2.60 and 2.00 in., respectively. The index line connects the TL product, 5.20 sq. in., and $D_o = 1\frac{1}{2}$ in. to intersect the D_e-scale at an equivalent diameter of 2.90 in.

REFERENCE

[1] D. S. Davis, ' Nomography and Empirical Equations', Chap. 8. Reinhold Publishing Corp., New York, 1955.

*Head, Department of Pulp and Paper Technology, University of Alabama.

What's New

in Plant · Equipment · Materials · Processes

CPE reference numbers are appended to all items appearing in these pages to make it easy for readers to obtain quickly, and free of charge, full details of any equipment, machinery, materials, processes, etc., in which they are interested. Simply fill in the top postcard attached, giving the appropriate reference number(s), and post it.

Fluid control equipment

At the Mesucora exhibition held in Paris last month, the Fisher Governor Co. Ltd. displayed a range of automatic fluid control equipment. This included automatic control valves (both pneumatic and electronically operated), the latest types of automatic valve operators, valve bodies of many different designs, several of which are specially made to withstand the extreme temperature and pressure ranges encountered in some types of plant, precision gas-pressure regulators of the kind used in the most modern gas-transmission systems, liquid level controllers with pneumatic and electronic signal outputs and level measuring units for mounting either inside or outside the vessel.

A new type (3560) Fisher valve positioner for diaphragm actuators was also shown. The design of this valve is the result of establishing optimum values for the many variables in the positioner loop. It provides high-speed action combined with excellent frequency response, good stability and high sensitivity. Air consumption is reduced to a minimum. Specially-shaped cams can be fitted to the instrument to change the basic flow characteristic of the control valve.

CPE 1664

Single-seat control valve

Crosby Valve & Engineering Co. Ltd. recently introduced a completely new *Masoneilan* single-seat heavy-duty globe valve body having wide flexibility of application. Extra-heavy top guiding of the plug eliminates the need for orthodox bottom guiding, reducing turbulent flow and trouble due to any solid particles which may be in suspension.

Special flow engineering features enable the new 20,000 series valves to have a much greater flow capacity, the capacity being approximately equal to that of the equivalent line-size double-seat control valve. The new valve will also withstand considerably greater out-of-balance pressure across the seat compared with that of an orthodox single-seat control valve, and still give tight shut-off and stable throttling control.

The 20,000 series valves are available screwed $\frac{3}{4}$ to 2 in. with trim sizes $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, $1\frac{1}{2}$ and 2 in. They are flanged $\frac{3}{4}$ to 10 in. with not less than four trim sizes for each line size valve. Standard materials are a carbon steel body and stainless-steel trim, and other materials are available to order. This new valve adds the performance characteristics of an angle-type control valve to the advantage of the simplified pipework of a straight-through type of body. It has high capacity, high permissible pressure drop, minimum working parts in contact with the fluid and a large range of interchangeable trims which enables it to suit a wide variety of applications. **CPE 1665**

Air filter

The *Trion* electronic air filter, marketed for industrial applications by W. C. Holmes & Co. Ltd. since 1956, has been redesigned to meet arduous operating conditions encountered in industry. It will in future be known as the *Industrion* electrical air filter.

The new filter is of much sturdier construction than its predecessor, the collecting cell is fabricated from a heavier-gauge aluminium and the supporting framework and ionising section support bar have been strengthened. Another advantage is that the insulators are now positioned out of the main air stream; this facilitates cleaning and ensures greater reliability.

A further development is the introduction of a special heavy-duty filter which is intended for use on applications where the dust burden is higher than that handled by the standard filter. With this heavy-duty filter, pre-collectors of the multi-cell cyclone type are normally fitted to arrest any large particles which may be present in the extract system.

As opposed to the standard filter which is cleaned by washing, heavy-duty filters are normally arranged for dry removal of the dust, the complete filter section being vibrated to dislodge the collected dust which falls into storage hoppers below the filter. The cleaning operation occupies only a few seconds and the filter can be immediately returned to line. One of the advantages of this system of cleaning is that the filter can be frequently cleaned, thus allowing a high dust burden to be handled. **CPE 1666**
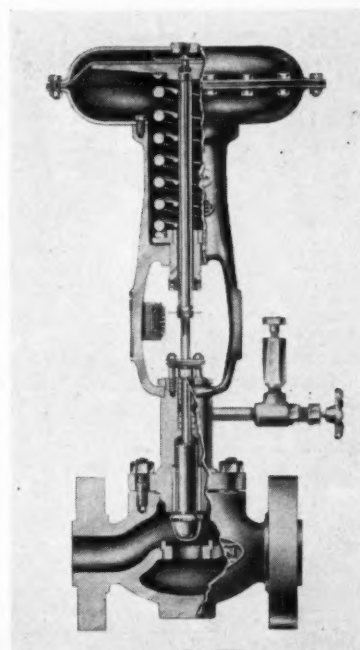
'Masoneilan' globe valve

Dry honer

All manufactured articles require some form of surface finish, which may consist of either a protective or decorative coating, or even an effect imparted to the material itself. The *Vacu-Blast* dry honer offers these facilities.

The dry feeding of fine cleaning media, sometimes as fine as 600 mesh, has always presented certain problems, as the particles tend to 'pack'. This tendency has been overcome in the past by the use of liquids as propellents and, whilst liquid or 'slurry' honing is an established practice in many processes, the possibility of dry feeding equally fine cleaning media using compressed air only as the carrier, presents many advantages. The dry honer, by means of feed aeration, eliminates the necessity for wet or slurry honing.

Where a fine matt finish is required as, for example, for plating or chroming, it is of equal importance to ensure that the surface is uniform. This can only be achieved by retaining the particle size of the cleaning media. In the dry honer, all particles below the required mesh size are continuously extracted and carried over by cyclonic action. By this action, a uniformity of surface is ensured, and rejects reduced if not entirely eliminated.

The machine is available in three sizes giving internal working dimensions of 23 in. × 23 in., 27 in. × 27 in. and 30 in. × 36 in. In the two larger cabinets provision is made for the side-loading of components, and extended runways to further facilitate loading may be provided. **CPE 1667**
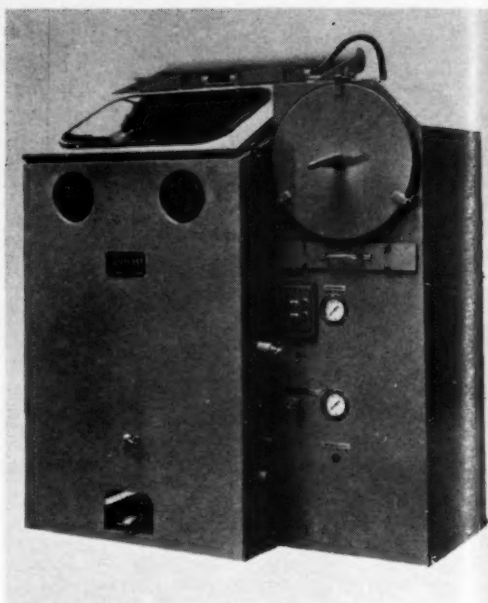

'Vacu-Blast' dry honer for obtaining various forms of surface finish

Computer-controlled boiler

Babcock & Wilcox Ltd. have designed a computer-controlled 200-MW boiler for automating large central station boilers. This project, scheduled for operation in 1962, is the outcome of a two-year design study in association with the Central Electricity Generating Board. It will provide programmed, fully automatic start-up, on-line operation and shut-down of a 1,350,000-lb./hr., 2,650-p.s.i. Babcock *Radiant* reheat boiler at the Board's new West Thurrock generating station.

A Ferranti *Argus* digital computer, with high-speed transistorised equipment designed specially for process control, will take over the usual duties of the human operator who now becomes the supervisor of the control system.

The computer will monitor approximately 150 metal and bearing temperatures, and will process all this information in accordance with its programme to provide 194 digital drives.

In addition to automatic control of the boiler, the computer will continually monitor running plant, take corrective action in emergencies and provide a printed log of plant operations and a record of important temperatures, pressures and flows. It will also calculate up-to-the-minute factors of boiler performance and efficiency. **CPE 1668**

Electric furnace

At the National Industrial Production Show held in Toronto last month, Morganite Exports I.td., a member of the Morgan Crucible Group, exhibited a working muffle-type electric furnace fitted with *Crusilite* silicon carbide heating elements.

Crusilite elements consist of one-piece silicon carbide tubes, in which the hot zone is produced by cutting a spiral in the centre portion. The absence of joints between hot and cold zones eliminates a potential source of failure present in other silicon carbide elements. The great advantages of this form of heating are ease of control, simplicity of design, cleanliness and absence of flue gases. Temperatures up to 1,575°C. are obtainable.

These elements are made in a variety of sizes, and numerous special types are obtainable. The novel double-spiral type has both electrical connections located at the same end, enabling the element to hang vertically downwards through the roof or project upward through the hearth or point inward through the walls of even the largest furnace. **CPE 1669**

Control valve

A new range of control valves known as the *Brodie* 500 series control valve has been developed mainly for the petroleum industry, but it is felt that it should be of considerable interest to many other industries.

The valve can be actuated with single or multiple pilots operated
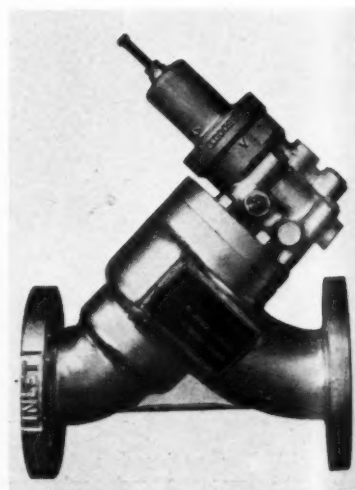
'Brodie' 500 series control valve

hydraulically, electrically or pneumatically. Some of the duties it can perform are remote control, differential pressure, rate of flow, pressure relief, pressure regulator, surge control, check valve, thermal pressure relief, and safety shut-off. The valves, from 2 to 12 in., up to 600 p.s.i. and temperatures of 150°F., have standard linear valve characteristics. **CPE 1670**
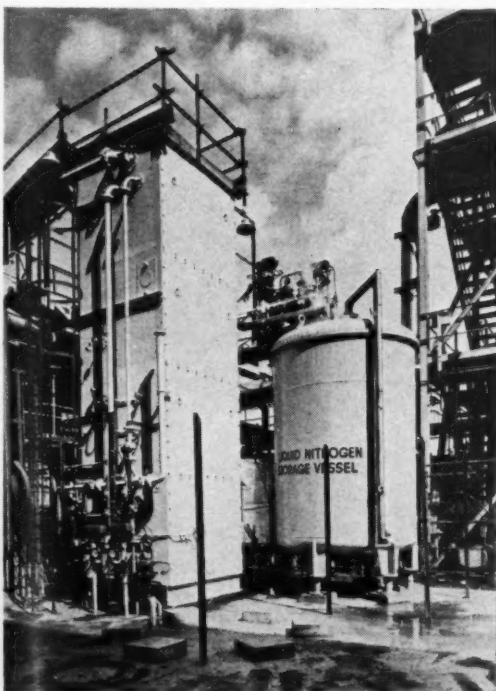
Nitrogen plant

There is a demand from many industries for moderate quantities of pure nitrogen to be used for blanketing vessels, purging and other purposes. The requirements are large enough to render uneconomical the transport from a distance of compressed gas in bottles or of liquid nitrogen in tanks. On the other hand, the conventional methods of producing nitrogen on site are not always satisfactory.

Petrocarbon Developments Ltd. have developed a new series of fully automatic plants to satisfy the demand of the U.K.A.E.A. for supply of high-purity nitrogen at an elevated pressure.

The nitrogen is produced by the fractionation of air at low temperatures in a single column operating at 100 p.s.i. and is delivered direct to the consumer at this pressure.

The capacities of the series range from 4,000 to 40,000 cu.ft./hr. of nitrogen and larger units can be provided.

For emergency storage and to cover short periods of peak demand, up to 10% of the product can be delivered as liquid and is then passed to a large vacuum-powder insulated storage tank. **CPE 1671**

Air-blast mixer

The Gardner *Airmix* is an entirely non-mechanical machine that gives a perfect mix by air blast to all types of dry powders, requiring less than 1 min. total mixing time. The *Airmix* consists of a vertical, smooth-surfaced cylinder with a lower conical section containing the mixing head. There are no working parts to maintain or wear out. Instead of blades or agitators the mixing head in the base contains a series of specially shaped and arranged nozzles through which compressed air is fed from a compressor in 1- or 2-sec. blasts, with a few seconds interval between each blast. The injected air agitates the powder in a spiral motion and gives a fast and thorough mix. A simple pre-set electric unit controls mixing time and the interval between each blast. Although air is admitted at high pressure, no pressure is built up inside the body. The machine, therefore, is safe at all times.

Textile filters that can easily be removed, cleaned and replaced are fitted. The mixer itself can be cleaned in a few seconds with one blast of air, thus saving time and labour.
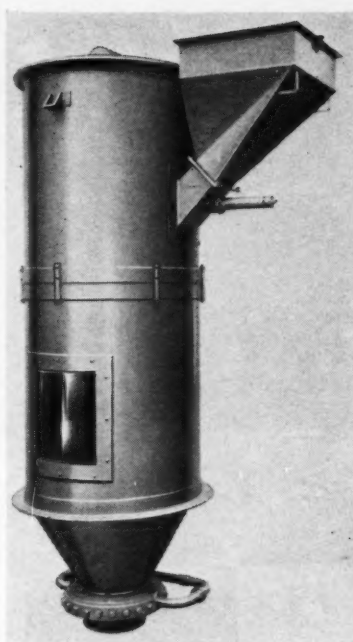
Gardner 'Airmix'

Airmix machines are available with working capacities ranging from 2 up to 800 cu.ft. and the largest machine will mix as little as a few pounds of material without any reduction in mixing efficiency. Modifications can be made to the mixer to enable it to be used as a combined mixer and sprayer to enable liquids to be added and thoroughly mixed with the powder. **CPE 1672**

Feed controller

A new automatic feed controller, specially developed for use in the pulverising, grinding and milling industry, is made by Lancashire Dynamo Electronic Products Ltd. This new control system has recently undergone a series of trials, which have shown substantial savings to be obtained over a wide range of applications.

In operation the mill motor loading is accurately measured by means of a current transformer and the controller provides stepless and accurate adjustment of the speed of the feed motor, so maintaining the desired mill loading as set at the control station.

The equipment is manufactured in its standard form in a range of ratings from 0.5 to 4 h.p., the smaller ratings being suitable for wall mounting. A wide range of motors is also available, including totally-enclosed types, and these can be supplied complete with suitable gearheads where required. **CPE 1673**

Fully automatic high-purity nitrogen plant built for the U.K.A.E.A. by Petrocarbon Developments Ltd.

To meet the demand of engineers using a smaller, shell-type or sectional boiler, John Thompson (Triumph Stocker) Ltd. have produced the 'Mini-Stoker'. Designed to burn efficiently and smokelessly cheaper grades of fuel now available, it enables engineers to comply with the requirements of the Clean Air Act. A 'Mini-Stoker' is here shown fitted into a sectional boiler which was previously hand-fired with graded coke.

mounted on a vibrator so that the screw, screw trough, discharge tube and screw bearings vibrate as one assembly. Feeders are supplied with an integrally mounted $1\frac{1}{2}$-cu.ft.-capacity hopper. Greater hopper capacities can be supplied by a supplementary hopper or a feeder pipe connecting the hopper with a remote bin. The vibratory action of the feeder overcomes sticking, bridging and flooding, and a constant level of material is maintained over the screw to eliminate feed rate fluctuations. **CPE 1676**

Dryer

A dryer offered by G.W.B. Furnaces Ltd. is made for applications requiring very dry air in small quantities up to 20 cu.ft./min.

A constant flow of dry air can be supplied readily to instrument controls, wave guides, small cubicles and other equipment. It is especially recommended for pilot-plant operations.

Once linked to the air supply and connected to any 230-V a.c. supply, the dryer automatically continues its cycle of adsorption and reactivation. If the electrical supply should fail the air supply will not be interrupted, and instruments or other air-operated apparatus will continue to function.

CPE 1677

Polyurethane pipe

Newalls Insulation Co. Ltd. displayed a range of rigid polyurethane pipe sections at the Engineering, Marine, Welding and Nuclear Energy Exhibition.

This very light material has high structural strength and a low thermal conductivity of 0.15 B.Th.U. in./sq.ft. hr.°F. and is said to be suitable for all types of low-temperature piping application.

The company are now engaged on contracts using polyurethane foams which may be foam dispensed or poured as a liquid mix into cavities of complex design or difficult of access. The liquid, expanding as it foams, follows the contour of the cavity walls, ensuring an intimate contact and good adhesion between the insulant and the shell.

These rigid foams are being employed in increasing quantities in refrigerated ships and land cold stores where high structural strength, low density and water absorption, together with low thermal conductivity, are all important factors in the choice of a suitable insulating medium.

Spraying techniques have also been developed using special machines for the covering of tanks, vessels and other plant.

CPE 1674

Flash-drying systems

Raymond flash-drying systems, offered in the U.K. by International Combustion Products Ltd., are used to remove definite amounts of moisture from damp, granular or fibrous material. The material is circulated in a hot, turbulent gas stream, causing the rapid transfer of heat and evaporation of moisture. When simultaneous drying and grinding is required, a disintegrator or pulveriser is included in the system.

The finished product is separated, cooled and conveyed in a dust-free plant operating under suction, and its dryness and particle size may be accurately controlled. The systems are recommended for drying materials such as wet coal cake and sewage sludge, and also for the preparation of chemicals, foods and fertilisers.

They are designed to accomplish drying under three distinct conditions: drying without disintegration, drying with disintegration, and drying and pulverising. **CPE 1675**

Volumetric feeder

A volumetric feeder has been developed with a new precision method of metering dry material into process using *Vibra* screws to feed tons/hr. and oz./hr. The *Vibra* screw is

Dryer for small quantities

Institution of Chemical Engineers

The 39th annual general meeting of the Institution of Chemical Engineers was held at the Park Lane Hotel, London, W.1, on Tuesday, April 25, 1961, with the president, Mr. W. K. Hutchison, C.B.E., in the chair. After the annual general meeting, Mr. Hutchison gave his presidential address on ' Industry, Science and the Chemical Engineer '.

The membership of the council of the Institution is now as follows:

President: Mr. C. E. Spearing.

Vice-presidents: Mr. C. M. Auty, Dr. G. P. Kane, Mr. K. B. Ross and Mr. E. S. Sellers.

Joint hon. secretaries: Mr. F. E. Warner and Mr. R. C. Odams.

Hon. treasurer: Mr. F. A. Greene. Ordinary members of council: Members—Mr. S. W. Adey, Prof. P. V. Danckwerts, Mr. L. Holliday, Mr. K. W. Palmer, Dr. B. Raistrick, Mr. R. V. Rutherford, Dr. J. A. Storrow, Mr. C. S. Windebank and Mr. E. Wollatt; Associate Members— Mr. W. G. Daroux, Mr. R. Parkins and Mr. P. A. Rottenburg; Co-opted Members—Mr. K. M. Curwen, Mr. K. W. Findlay, Mr. T. W. B. Flavel, Mr. G. U. Hopton, Dr. J. S. Hunter and Mr. A. S. White.

Butyl rubber contract

Esso Petroleum Co. Ltd. has awarded a contract to construct a butyl rubber plant at the Esso refinery, Fawley, to Foster Wheeler Ltd.

The new plant, which is expected to be completed by the end of next year, will cost about £4.3 million and produce 30,000 tons of butyl rubber p.a.

Oil gas plant

P.G. Engineering Ltd. has been instructed by the Alliance & Dublin Consumers Gas Co. to proceed with the building of a cyclic catalytic oil gas plant. The plant will consist of two units of the Segas process, producing town gas from heavy oil. The contract is to be completed by August 1962.

£ s d

CHEMICAL PLANT COSTS

Cost indices for the month of April 1961 are as follows:

Plant Construction Index: 184.9

Equipment Cost Index: 175.2

(June 1949 = 100)

£ s d

Coal washery

Simon-Carves Ltd. have received through their Canadian subsidiary, Simon-Carves of Canada Ltd., a contract to supply a coal preparation plant for the Crow's Nest Pass Coal Co., British Columbia.

The plant will be capable of cleaning 120 tons/hr. of ½-in. coal. It will be ready for commissioning in April 1962.

Participating in the contract, worth nearly £250,000, will be a Simon-Carves subsidiary — the Automatic Coal Cleaning Co. Ltd. of Carlisle— who will supply the feldspar jig washbox.

Naphthalene intermediaries

Representatives of Ciba Ltd., Basle, and Humphreys & Glasgow Ltd. have been in Bulsar, India, to finalise the details of the expansion programme of Atul Products Ltd. for naphthalene intermediates and fast-colour bases in the dyestuffs field.

Ciba will make available to Humphreys & Glasgow and Atul their manufacturing processes and know-how and generally will act in an advisory capacity. Atul personnel will be trained in the Ciba works at Basle, Switzerland, for operating the plant, which is expected to be ready in 1963. Humphreys & Glasgow will be responsible for engineering, planning and construction of the plant.

The complete project, of which only the intermediates section has been previously announced, will cost nearly £3 million.

Motors for nuclear power station

Lancashire Dynamo & Crypto has received an order from Fairey Engineering, sub-contracting to Atomic Power Constructions, for some 400 permanent magnet motors for operating the reactor control rods of the Trawsfynydd nuclear power station.

The motors will be insulated to operate in an ambient temperature of about 100°C., and will be operated from a variable frequency supply so as to have a final speed between 0.2 and 0.7 r.p.m.

Flue gas washing plant

Head Wrightson Processes Ltd. has been awarded a contract by the Central Electricity Generating Board, worth nearly £500,000, to build a flue gas washing plant, part of the extension to Bankside power station. This plant is designed to remove more than 95% of the sulphur from the oil-fired boiler flue gases.

Process cooling

What are the main features associated with cooling in the pharmaceutical and fine chemical industry? A special feature on Process Cooling and Refrigeration in the June issue of **Manufacturing Chemist** surveys this important subject. Other articles in this issue are: Parke Davis New Capsule Plant, by W. G. Norris; and Small-scale Manufacturing Equipment—Filters, by B. W. Burt.

The following articles appearing in our associate journals may be of interest to readers of CPE.

Paint Manufacture—Trends in the Design of Paint-making Machines, by W. G. B. Mills. Magnetic Printing Inks, by E. A. Apps. Flourescent Paints, by P. W. Sherwood.

Petroleum—Oil in Africa, by C. A. Fothergill. Turba-Film Processing for Petrochemicals. Recent Developments in Instrumentation and Control.

Fibres and Plastics—Manufacture and Dyeing of Polyamide Fibres, by R. S. Asquith and G. E. Styan. Low-temperature Radiant Heat Drying, by H. L. Smith.

Dairy Engineering — Buttermaking with Stainless Steel and Wooden Churns, by J. H. Smith.

World Crops—Progress in Weed Control in Malaya, by K. F. Kavanagh. Benefits Derived from the Use of Agricultural Chemicals, by E. Holmes.

Food Manufacture—Review of Refrigeration Plant for the Food Industry.

Automation Progress—Automation —Its Evolution and Future Direction, by J. T. Culbertson. Unmanned Station Controls Town's Gas, by W. Lloyd-Ellis.

Specimen copies of these journals and subscription forms are available from the Circulation Manager, Leonard Hill House, Eden Street, London, N.W.1.

Nuclear Notes

Progress on A.G.R.

The construction of the prototype advanced gas-cooled reactor is now approaching its final stages at Windscale, in spite of labour troubles which have caused considerable delays. It is intended that construction will be completed in July and that the reactor will be handed over to operations staff for fuel loading in the late autumn.

Inside the reactor vessel the graphite core and its supports are complete, and the neutron shield has been erected. The can failure detection pipes are being fitted and connected to the precipitators which have already been installed.

The production of uranium oxide pellets for the fuel elements is progressing well; quantity production of components for the stainless-steel canned elements has started satisfactorily and the assembly plant is being commissioned. In spite of the difficulties experienced with beryllium production, and the corrosion problems which have arisen, a quantity of beryllium-canned fuel elements are being produced.

Reactor in Taiwan

The nuclear research reactor built by U.S. General Electric for National Tsing-Hua University, Taiwan, has gone critical. The open-pool-type reactor was completed last December and sustained its first chain reaction in April.

In this type of reactor, the core is submerged in ordinary water that cools it, shields personnel from radiation and slows neutrons to the desired energy range. The core is suspended from a bridge that can be moved to either of two pools, enabling experiments to be set up in one pool while the other is in use.

Particle accelerator research

The U.K.A.E.A. and the National Institute for Research in Nuclear Science have agreed that the development of particle accelerators hitherto carried out by the accelerator division, A.E.R.E. Harwell, should be the responsibility of the Rutherford laboratory of the National Institute for Research in Nuclear Science. Mr. L. B. Mullett, the head of the accelerator division, has joined the Rutherford laboratory as assistant director for accelerator and applied physics. Other appropriate staff transfers have already taken place.

Luminous watches and clocks

The U.S. Atomic Energy Commission has amended its regulations governing the licensing of by-product material (radioisotopes) to permit the use of tritium on the hands and dials of luminous watches and clocks.

Tritium (hydrogen 3) is a radioactive material that emits no penetrating gamma radiation and whose low-energy beta particles do not have enough energy to penetrate a watch crystal or the insensitive outer layer of the skin. The use of tritium in place of radium as the activating agent for phosphorus on the hands and dials of luminous timepieces would reduce the amount of exposure of users to radiation.

Radium, which has been used in luminous timepieces and clocks since early in this century, emits alpha, beta and penetrating gamma rays. Recently, substitutes for radium have been developed using other radio-active isotopes which have become available as by-products of the atomic energy programme. Tritium is among those which are considered safer than radium.

The amount of tritium on acceptable timepieces is limited to 25 millicuries for each watch or clock. The amount on replacement parts is limited to 5 millicuries on each luminous hand and 15 millicuries on each dial.

Japanese agreement

A long-term agreement has been concluded between G.E.C. Ltd. and Nippon Denkyoku Kabushike Kaisha covering the manufacture in Japan of special types of graphite developed by G.E.C. laboratories for use in nuclear plant. Initially for a period of 10 years, the agreement is subject to the approval of the U.K. and Japanese Governments.

Two types of graphite are involved —one of low permeability and the other substantially impermeable. The low-permeable material is produced by impregnating normal graphite with a form of sugar. Impermeable graphite involves a novel method for building up the carbon structure. It is thought

Preparing part of a gas circulator for assembly under nuclear clean conditions at the Erith works of G.E.C. Eight gas circulators will be used for circulating the coolant through each reactor at the Hunterston Nuclear Generating Station which is being built for the South of Scotland Electricity Board by the G.E.C. and Simon-Carves Atomic Energy Group
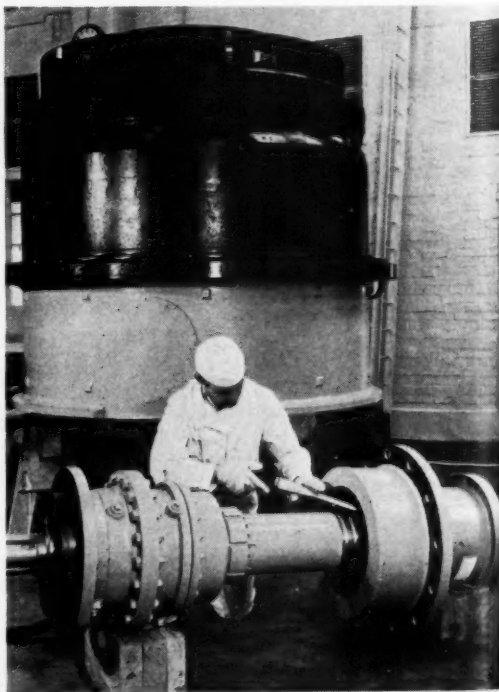
that these materials could be used outside the nuclear field, for instance in the chemical industry.

Under the terms of the agreement G.E.C. will pass on to the Japanese company all information available on the processes and will assist the company to set up the necessary manufacturing plant. G.E.C. will provide technical staff to help with the building of the new plant and will undertake the training of Japanese engineers.

Utilisation of reactor heat

A device known as a plasma diode, which utilises the heat produced in the centre of nuclear reactor fuel elements for the direct generation of electricity without the necessity for mechanical rotating equipment, is being tested by U.S. General Electric's Vallecitos atomic laboratory.

A thermionic converter produces an electrical current by boiling electrons off a cathode or hot metal plate and collecting them on an anode, a cooler plate.

It is thought that a refinement of the present experimental diodes would permit a sizeable increase in the electrical output of nuclear power stations at slight additional cost.

Application of such devices to conventional steam generating stations does not appear practical, since the normal temperature levels achieved in such stations are too low to permit efficient operation of such direct conversion devices.

The plasma diode under development is a high-temperature thermionic device using caesium gas and a uranium-bearing cathode.

These diodes would be built into nuclear fuel elements, where the fissioning of the uranium in the cathode would provide the high temperatures—in the range of 4,500°F.—needed for efficient direct conversion. An electrical lead from the fuel element would draw off the electricity.

In addition to the directly produced electricity, lower-temperature heat rejected through the walls of the fuel element would also be used to produce electricity by boiling water to make steam for the operation of turbine generator facilities.

Three British research reactors

The British Government have agreed to provide three low-powered reactors for teaching and research in universities. Announcing this recently, Mr. Denzil Freeth, Parliamentary Secretary to the Ministry of Science, stated that the cost of each reactor would be about £100,000 and that the

A workman inspecting an underground stainless-steel vessel which will house a sodium-cooled graphite-moderated reactor for the Hallam, Nebraska, Nuclear Power Facility. The vessel is 33 ft. deep, 19 ft. in diam. and weighs 50 tons. Supports for moderator cans and fuel elements are arranged in honeycomb fashion in the bottom grid plate. Atomics International are building this reactor

Government would be bearing almost the full cost. At present, negotiations were going on to decide the best place for the reactors. One will be in Scotland (in the Glasgow area), one in Lancashire and the third will be in the London area.

Ispra nuclear research centre

The Italian Government has formally handed over to Euratom the Ispra nuclear research centre.

The centre thus becomes the first major establishment of the joint research centre and so far the only general-purpose one to be set up by Euratom. Over 800 people are employed at Ispra, two-thirds of whom are technicians and research workers from the six Community countries, including the 150 Italian scientists who will be working at the centre for a further two years under the Italian National Committee for Nuclear Energy.

By the end of 1962 it is planned that the centre will have a staff of 1,500, excluding auxiliary personnel.

Space prototype reactor

A tiny prototype lightweight reactor to generate heat for the production of auxiliary power for space vehicles achieved criticality recently. The reactor weighed 200 lb. without shielding and is fuelled with a uranium-zirconium hydride alloy; the core is

13 in. high and 9 in. diam. Designated SNAP 2 development system (S2DS) reactor, it is the second to be designed, constructed and operated for the Atomic Energy Commission by Atomics International.

The core generates 50 kW of heat. In an operational device the heat from the core would be transferred by a liquid sodium-potassium coolant to a boiler containing mercury. The mercury vapour would be directed into a miniature turbine for the generation of 3 kW of electricity.

The reactor will be mated to its power conversion unit for ground testing of the complete SNAP 2 system later this spring. After this testing programme has been completed, a system with flight configuration will be mounted in a satellite nose cone for additional ground testing.

Nuclear ship propulsion

The O.E.E.C. European Nuclear Energy Agency's recently formed study group on ship propulsion, under the chairmanship of Dr. S. Eklund of Sweden, has discussed the possibility of European joint action in this field. The study group has set up two technical working parties to examine the economic potentialities of nuclear ship propulsion, and the means whereby a European joint undertaking could be set up for the construction and operation of a nuclear ship.

Glass-enclosed reactor

The first nuclear research reactor, so safe that it is enclosed in glass and located in the heart of a major university campus, has started operating at the University of Washington in Seattle. It was designed and built by American Machine & Foundry Co.'s atomics division at a cost of $500,000. A feature of the design is that the public will be able to view the reactor's research operations through a number of large windows.

The reactor, known as an *Educator* type, an improved version of the *Argonaut* type used at the International School of Nuclear Science and Engineering at the U.S. Atomic Energy Commission's Argonne National Laboratory, was developed specifically for university training and associated research.

Essentially a light - water and graphite - moderated reactor, the *Educator* utilises water as both moderator and coolant which is confined completely to the fuel boxes. Thus the reactor provides both the safety of water expulsion from the core and the convenience of a solid moderator. The Washington reactor has a large graphite prism surrounding the core proper which is enclosed by a shield consisting in part of poured concrete and in part of movable concrete blocks. This arrangement of shielding prevents all radiation streaming and keeps radiation levels on the operating floor well below tolerance. It has been designed to operate at a power range of 10 to 100 kW. The core contains 3.2 kg. of enriched uranium fuel.

JASON operated at 100 kW

Hawker Siddeley Nuclear Power Co.'s privately owned JASON reactor has recently been operated at 100 kW —the highest rating that any reactor of this design has so far achieved, and ten times the rating for which this particular version was originally designed.

The work which resulted in this was part of the development programme on advanced types of JASON now being undertaken at Langley. The experiments were carried out in accordance with the terms of the Ministry of Power's licence for the company's nuclear site and at the same time provided valuable information in support of the safety regulations for which the Ministry is responsible to the general public.

The operation at 100 kW was part of a series of tests designed to yield information on the safety characteristics of reactors now in the design

A technician examining the reflector of a 200-lb. compact nuclear reactor for space. It is called the S2DS reactor and has started operating at Atomics International's nu clear field labor atory as part of the Atomic Energy Commission's programme to provide systems for nuclear auxiliary power (SNAP) for space vehicles. The 9 in. x 13 in. core is surrounded by the reflector units

stage. Information was obtained on the effect of pump failure during operation at 100 kW and the removal of decay heat by thermal convection of air, following the reactor scram (with water dumping) from full power.

Three runs were made at 100 kW, each of about 20 min. The cooling supply was as for 10 kW. In two of the runs, the coolant supply was completely interrupted so that the behaviour of the reactor could be observed. When no attempt was made to compensate for the rise in temperature, the power quickly fell and the reactor stabilised out at 10 kW. When the control rods were withdrawn to compensate for temperature rise, the power remained steady until they were fully withdrawn and the power then fell to about 20 kW.

Mobile nuclear plant

The prototype reactor for the world's first mobile nuclear power plant achieved criticality on March 30, 1961, at the U.S. Atomic Energy Commission's national reactor testing station in Idaho.

Following several months of low-power testing, this reactor will be coupled to the power conversion equipment—a gas turbine and generator capable of producing 300 to 500 kW of electricity. The reactor has been under development at Aerojet-General Nucleonics, San Ramon, California, for about five years. It is the world's first direct-and-closed cycle gas-cooled nuclear power system.

Nitrogen gas heating in the reactor core is used to drive the turbine and then is returned to the core.

The entire plant is skid-mounted in six packages totalling less than 38 tons and can be transported. The reactor is water moderated and generates about 3,400 kW of heat. It can be placed in full power operation 12 hr. after arrival at a remote site and moved to a new location 24 hr. after shut-down.

Reactor in Portugal

A research reactor designed and built by American Machine & Foundry Co.'s atomics division was constructed recently near Lisbon. The reactor is part of the facilities of the Junta de Energia Nuclear, which also includes a physics department with a linear accelerator, a Van de Graff generator, a radiation chemistry building, and a pilot plant for future uranium refinement.

Swedish homogenised reactor

Development work on a new type of homogenised heavy-water reactor has been going on in Sweden since 1959 and the results are promising, according to a report by the Swedish Atomic Energy Co. In the homogenised reactor the fuel elements are spread uniformly throughout the tank volume, whereas in previous Swedish reactor designs they have been placed in clusters. Furthermore, the same quantity of heavy water is used both as moderator and as coolant.

Orders and Contracts

Portuguese fertiliser project

Uniao Fabril do Azoto will erect a new fertiliser project at Barra a Barra, Portugal, near Lisbon. The project, scheduled for completion in 1962, will consist of a 180-metric-tons/day ammonia plant, a 40,500-metric-tons/yr. urea unit, a nitric acid plant, an ammonium nitrate plant and a nitro-limestone plant. The M.W. Kellogg Co., New York, and two of its subsidiaries have been awarded contracts covering the ammonia and urea plants, project offsite facilities, and construction of all major process facilities.

Engineering of the ammonia and urea plants will be carried out by the M.W. Kellogg Co. and Kellogg International Corp., London. K.I.C. will also be responsible for off-site facilities and in addition will handle the procurement of materials in the United Kingdom for these plants and facilities. Kellogg of Panama will be responsible for local procurement in Portugal and will carry out all construction with the exception of administrative buildings.

Engineering and procurement for the nitric acid plant, the ammonium nitrate plant and the nitro-limestone plant will be undertaken by C. & I./Girdler International Ltd. of Nassau, Bahamas. The nitric acid plant and the ammonium nitrate plant are scheduled for operation in early summer. Initial operation of these units will utilise ammonia imported from nearby Portuguese plants.

Turbo-blower

The General Electric Co. Ltd. has recently received a repeat order valued at £139,000 for the supply and installation of a second 100,000-cu.ft./min. turbo-blower at the Cleveland works of Dorman Long (Steel) Ltd. This, and the other machine which is already under construction, will be placed alongside two existing 90,000-cu.ft./min. blowers which were also supplied by the company.

The blower, which is to supply air to blast furnaces, will be of the centrifugal type, having three impellers each of 66 in. diam. running at speeds up to 3,200 r.p.m.

Geothermal project

The Chemical & Insulating Co.'s Darlington plant is at present engaged in producing 85% super-magnesia insulation for the geothermal project which uses the hot springs at Wairakei, New Zealand, to generate power. Aiton & Co. Ltd., of Derby, are supplying and erecting three 30-in. transmission pipelines, each two miles long, to carry steam from the boreholes to the generating station and have placed the order for the insulation with the Chemical & Insulating Co., who are also supplying the insulation materials for the generating station.

Sulphuric acid concentration

Compania Mexicana de Explosivos S.A., Mexico 1, D.F., have awarded to Chemical Construction (G.B.) Ltd. a contract to supply full process design and detailed engineering services relating to a 30 short-ton/day sulphuric acid concentration plant of the submerged combustion type. The new plant will be erected in Mexico by Compania Mexicana de Explosivos S.A., a wholly owned subsidiary of E. I. duPont de Nemours & Co.

Ethylene pipeline

Constructors John Brown Ltd. have been awarded a contract for the construction of the 78-mile 6-in. ethylene pipeline between the Esso refinery, Fawley, and the new works of I.C.I. at Severnside, near Bristol.

The contract for the supply of the 6-in. steel line pipe, weighing about 2,700 tons, has been placed with Stewarts & Lloyds Ltd.

Construction is expected to be completed this year at an estimated cost of £850,000 including easements and compensation.

Sea-water distillation

Bennis Thermoflash Ltd. has received a contract for the supply of a self-contained sea-water distillation plant for the ruler of a sheikhdom in the Arabian Gulf area. The plant will be based on the *Thermoflash* process and will incorporate a steam generator and diesel-driven alternator to provide the heat and power for operating the distillation equipment. The output of pure water will be 25,000 Imp.gal./day.

Built into the equipment are fresh-water storage tanks, which also act as pontoons during the off-loading, since there are no port facilities at the point on the Gulf where the plant has to be landed. It will, therefore, have to be dropped into the sea some miles from the shore and towed to its foundations.

Fluid mixers

Lightnin Mixers Ltd. despatched recently to Australia one of the largest consignments of fluid mixers to be exported from the U.K.

The order comprised 47 units from the standard Lightnin range, many units fitted with mechanical seals; the mixers will be used in a new synthetic rubber plant for Australian Synthetic Rubber Co. Ltd.
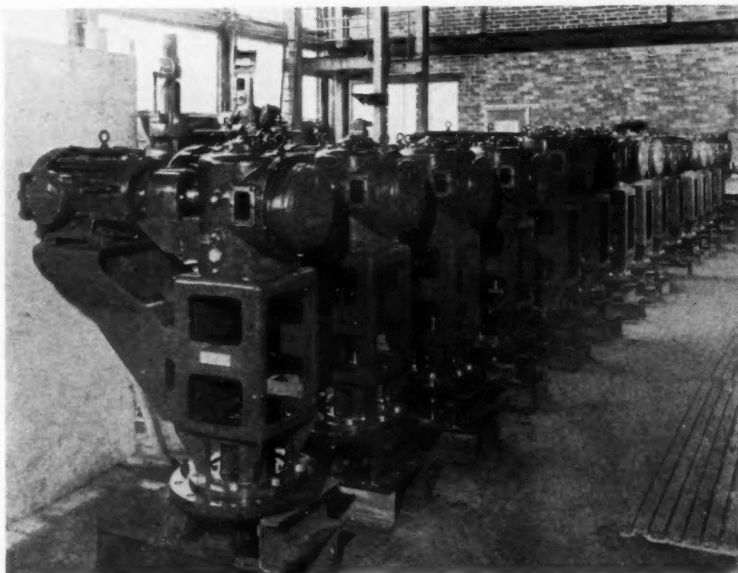
Part of the consignment of fluid mixers recently exported to Australia

New Books

Nuclear Reactor Containment Buildings and Pressure Vessels. Butterworths, 1960. Pp. 572. 100s. net.

This book contains the proceedings of a symposium organised by the Department of Mechanical, Civil and Chemical Engineering of the Royal College of Science and Technology, Glasgow, which was held at the college in May 1960. At the symposium 24 papers were presented by authors from the Atomic Energy Authority, an inspection authority, institutions of higher education and industry in this country and abroad.

These papers were discussed in detail at the symposium and the inclusion of the discussion in this book greatly enhances its value.

The book is divided into six sections with headings:

(1) Current practice and future trends (four papers).
(2) Design studies and methods of stress analysis (five papers).
(3) Shell research—analysis and experiment (ten papers).
(4) Engineering design, fabrication, erection and testing (three papers).
(5) Open topic contributions (two papers on brittle fracture).
(6) Summaries of the proceedings.

The subjects treated in the first section include a comprehensive review of the design of pressure and containment vessels for several types of reactor, a description of the considerations which lead to the formulation of the specification for these vessels and an examination of the suitability of concrete as a material for containment.

One paper from the second group is an examination of a containment project in the United States; the second can be conveniently classified with one of the fourth section as a study of the engineering design of a containment building. These papers admirably illustrate the manner in which a compromise between the ideal and the practicable is made.

Two other papers from the second section, together with four from the third are representative of the more advanced type of analysis which is carried out by pressure vessel designers who are conscious of the fact that the standard codes in current practice do not guarantee the safety of vessels designed according to their

rules. As is to be expected, these papers consist mainly of the manipulation of previously known results to suit the loading and boundary conditions of the problems. The remaining paper of the second group and four of the third are of a more fundamental nature, but two or three at least are in a form suitable for immediate use in design offices. The mathematical knowledge required for an understanding of these papers is comparable with that needed to study 'The Theory of Plates and Shells' (Timoshenko and Woinowsky-Krieger) or 'Stress in Shells' (Flugge). The third group also contains two reports of numerous experiments carried out to investigate the behaviour of shells with attachments to which external loads are applied.

The second paper of the fourth section describes the method of construction of nuclear vessels in the workshops and at site adopted by one manufacturer. The third paper of this section is an interesting account of the site air testing of large vessels; some deflection and stress measurements are quoted.

The two papers on brittle fracture are both by Continental authors, who are in agreement that the present methods of testing the ductility of steels do not lead to a reliable assessment of the 'transition temperature'.

In conclusion, it can be stated that this book will be of interest to those connected with the nuclear field and indispensable to those actively engaged in the design of reactor pressure vessels and containment buildings.

M. B. BICKELL

Gases at High Densities and Temperatures. By Yu. N. Ryabinin. Pergamon Press Ltd., London, New York, Paris, 1961. Pp. vii + 52. 25s. net.

This volume is a translation, by H. K. Zienkiewicz, of a Russian monograph, first published in Moscow by Fizmatgiz in 1959, and describes an experimental technique for studying gases at high temperatures (up to 9,000°K.) and high pressures (up to 10,000 atm.). For the work reported, the author was awarded the D. I. Mendeleev prize.

The technique used to obtain the high temperatures and pressures is in principle simple, being the adiabatic

(and, it is claimed, isentropic) compression of the gas in a closed cylinder by a heavy 'free' piston 'fired' by means of a compressed working gas. In this way the high temperatures and pressures are held for only a very short time, and heat losses from the hot gases to the cylinder walls are very small; this has the double advantage of giving almost adiabatic conditions and of keeping the apparatus itself cool. Full details of the method and apparatus used are described and many of the experimental difficulties are discussed.

The gases considered were monatomic (argon) and diatomic (air and nitrogen) with a few experiments using carbon dioxide, in order to extend information to triatomic gases. The particular properties investigated were light emission, electrical conductivity and the state of the dense gas at high temperatures. Many interesting factors emerged from the work. Perhaps the result of most general interest was that argon at 2,000 to 7,000 atm., at a temperature of 8,000°K., behaved almost as an ideal gas.

It is always of interest to read of Russian scientific achievements and techniques, and this booklet is of great value in this respect. It should prove of particular use to those scientists and engineers interested in the properties of gases at high temperatures and pressures.

P. J. KING

The Fundamental Atomic Constants. By J. H. Sanders. Oxford University Press, 1961. Pp. 28. 10s. net.

The author has produced a small volume reviewing the determination and the accuracy of measurement of certain constants. The constants covered in this work are the electronic charge e, the electronic mass m, the mass of the proton M, the velocity of light c, Planck's constant h and Avogadro's number N. Two other constants, G (the gravitational constant) and k (Boltzmann's constant), are excluded from this review as they have little bearing on atomic phenomena. In the chapter devoted to earlier measurements the fact is pointed out that, although the constants quoted above are formally independent it is difficult to measure most of them alone to a high degree of accuracy. Recourse must therefore be made to the measurement of quantities involving several of these constants, e.g. the Rydberg constant.

The most notable exception is, of course, the velocity of light.

Accordingly a chapter is devoted to this important measurement reviewing progress from the rotating mirror methods to the later, more precise, electronic methods using microwaves or employing a Kerr cell as a 'chopper'. Clear and helpful descriptions of these methods are given. The chapter on recent precise methods of measuring the other constants will probably be of much interest to chemists, as a number of novel methods are included. Some of these depend on devices analogous to cyclic particle accelerators and others upon measurement of the hyperfine structure of hydrogen and deuterium using microwave spectroscopy.

A curious omission in a publication of such recent date is the absence of any reference to the proposed new unified chemical and physical scale of atomic weights based upon the standard $^{12}C = 12.00000$. This change has been approved by the I.U.P. and will be confirmed in 1961 by I.U.P.A.C. This new scale will affect some constants, e.g. N will be reduced by some 43 p.p.m. on the chemical scale and rather more on the current physical scale. Repercussions must follow on some constants whose values are determined from a knowledge of these quantities.

This omission, however, does not detract from the value of this work in presenting a concise and readable account of the establishment of the constants whose values are so often taken for granted. An impressive feature is a copious list of 193 references in a volume of 73 pages.

G. L. REED

The Applied Science of Rubber. Edited by W. J. S. Naunton. Edward Arnold (Publishers) Ltd., 1961. Pp. 1,191. £8 8s. net.

It would not be exaggerating to claim that this is both the most comprehensive as well as the most authoritative book ever published on the chemistry, physics, biology and technology of natural and synthetic rubbers. That there has been dire need for such a book is evident to any one who has ever worked in the rubber industry. Hitherto the literature dealing with this subject has suffered from the great drawback that it has become out of date very soon after its publication—this fact reflects the rapid rate of progress within this field.

It would have been beyond the physical and mental capability of one individual to write such a book single-handed and, as a result, each chapter has been compiled by leading specialists, the whole volume being edited by that doyen of rubber science, Dr. W. J. S. Naunton. The chapters deal with the applied science of rubber in every state throughout its transformation from latex to the finished article. In addition, valuable surveys on present-day methods of testing and quality control and theories of vulcanisation are presented.

The most revealing point made constantly throughout the volume is the lack of any fundamental knowledge on many of the common processing operations used in the rubber industry. Processing (according to Dr. J. R. Scott's definition) denotes those operations that come between the initial mastication of the rubber and the vulcanisation of the finished article as, for example, mixing, calendering extrusion, moulding and combining with textile fabrics. It is a sad fact that very few chemical engineers have ever attempted to apply their particular discipline to these problems. Apart from some investigations into the mechanism of mixing and extrusion no chemical engineering work of any basic significance has been devoted to rubber technology. This is partly due to the complexity of the medium, rubber being a non-Newtonian liquid; orthodox chemical engineers have so far dealt mainly with Newtonian bodies. In this context the flow analysis of rubber in an extruder (p. 310) is particularly significant. The various forces which propel the rubber over the screw towards the orifice have been analysed; the discrepancy between theoretical and practical formulae has been attributed to slippage of rubber over the metal. The relationslip of slippage to expansion at the orifice die is most interest-

ing—an analogy might be made with the mixing mechanism in shear-blade mixers. This is one example of an investigation that would benefit by chemical engineering analysis!

Throughout the volume a detached and objective view has been taken by the contributors with respect to the plethora of developments and publications pertaining to the rubber industry. The view that 'the rubbery state,' not rubber, is of primary interest, is stressed throughout and, for this reason, synthetic macromolecules which exhibit rubbery elasticity at ordinary temperatures have been treated on the same level as the rubber from *Hevea Brasiliensis*. The only criticism that could be made is with respect to balance. It might be argued, conceivably, that a little more space could have been devoted to the technology chapters at the expense of those chapters dealing with rubber chemistry (which overlaps inevitably with high-polymer chemistry, on which subject excellent literature is already available). All concerned in the publication of this volume must nevertheless be congratulated and we must only hope that bi- or tri-annual revisions of this volume will be published—this will then serve as a 'Handbook of Rubber Science and Technology'.

I. L. HEPNER

Translation from Russian for Scientists. By C. R. Buxton and H. Sheldon Jackson. Blackie, 1960. 30s. Pp. 299.

This is a useful work for the scientist who wants to acquire a reading knowledge of Russian. Sixteen pages of introductory matter designed to diminish the terrors of a strange alphabet and language are followed by 70 pages of logically arranged and clearly presented grammar.

The reader progresses from aerographical names (which are mostly straight translations) to words, phrases, sentences, annotated texts and, finally, to extracts from Russian scientific publications, acquiring a gradually enlarging vocabulary as he progresses. There are 115 pages of vocabulary.

Some effort is made to teach roots and the principles of Russian word-building, but more might be done. In spite of all the loan-words from Western languages there remains a large number of purely Slavonic words even in technical Russian and the ability to spot the roots, prefixes and suffixes forming these can save much weary work with dictionaries.
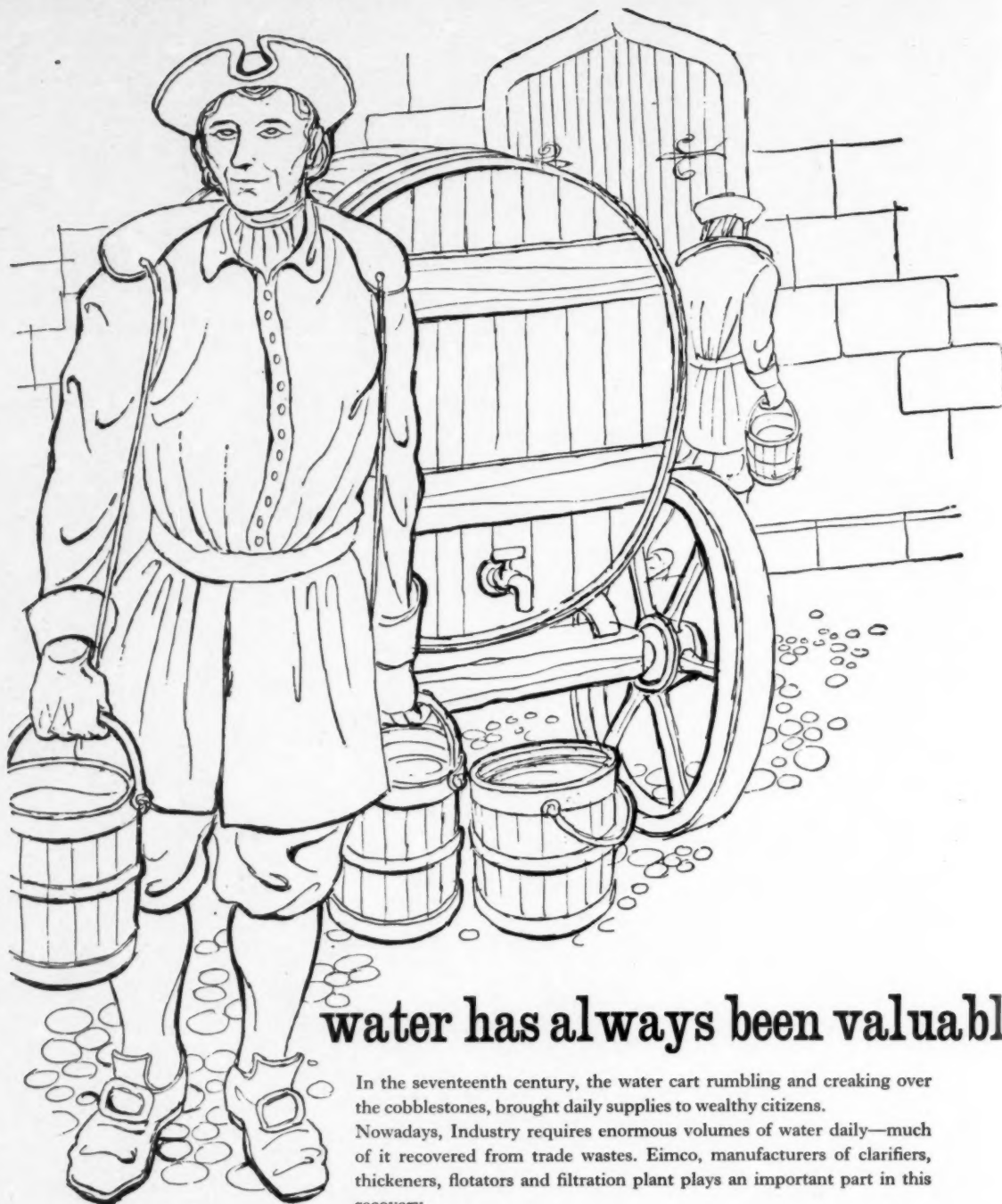
D. J. CAMPBELL

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Nigerian asbestos factory

Turner & Newall Ltd. intend to build a factory in the Eastern Region of Nigeria covering 120,000 sq. ft. It will produce eventually 17,000 tons/yr. of asbestos products. Test borings for water on the site are nearing completion. Cement will come from an established factory at Nkalago, 20 miles from the new factory, and asbestos will be landed from Canada at Port Harcourt, from where it will be transported 170 miles by rail.

Baglan Bay works

British Hydrocarbon Chemicals Ltd., jointly owned by the British Petroleum Co. Ltd., and the Distillers Co. Ltd., is to construct a plant at Baglan Bay near Port Talbot which should come into operation by the end of 1962. As feedstock the plant will use a light petroleum distillate received from the B.P. refinery at Llandarcy, some three miles away. Operations will be based on a steam cracker, producing the olefines, ethylene, propylene and butadiene from the resultant mixture of cracked gases. Part of the ethylene will be transferred to another B.H.C. plant on the same site where it will be combined with chlorine to make ethylene dichloride used for the manufacture of vinyl chloride. The remainder of the ethylene produced will be transferred to the new plant for the manufacture of styrene monomer. Butadiene will be extracted and refined for sale for the manufacture of synthetic rubber and other co-polymers.

Maleic anhydride plant

The Heavy Organic Chemicals Division of I.C.I. is to construct a maleic anhydride plant at the company's Wilton works on Tees-side. A new process will be used in which butene is oxidised with air, and the plant will have a capacity approaching 10,000 tons p.a. of maleic anhydride when fully developed. The construction of this plant is a further step in the utilisation as chemical raw material of the butenes obtained from the division's olefine plants at Wilton.

Maleic anhydride is an important raw material in the production of resins for reinforced plastics and surface coatings. It is also used in the preparation of agricultural chemicals, insecticides and other derivatives.

Crude oil distillation plant

I.C.I. Ltd. are to build a plant capable of distilling about 1 million tons of crude oil p.a. on a site on the north bank of the River Tees. Agreement has been reached with Shell-Mex & B.P. Ltd. whereby they will make available to I.C.I. the crude oil for processing. The plant will cost several million pounds and is due for completion before the end of next year.

The plant will consist essentially of a distillation unit designed to give flexibility, in order to permit a variety of crudes to be processed and to vary the end products. The light distillate (naphtha) produced will provide a proportion of the feedstock requirements for the division's three olefine plants at Wilton, whilst other products will be marketed by Shell-Mex & B.P. Ltd. The Heavy Organic Chemicals Division of I.C.I. will be responsible for erecting and operating the distillation plant.

The site is on reclaimed land with a good river frontage on which a jetty will be built to handle the crude oil and also products despatched by river from the site. Only a part of the area will be taken up by the present scheme. There will be ample room for storage facilities and for future developments. The existing pipeline system linking the Wilton and Billingham I.C.I. works, which together form the largest petroleum chemicals complex in Europe, runs alongside the new site, so that transfer of refined products to either will be facilitated.

Research Institute expansion

The practice of J. A. Radley, chemical consultant, has been registered as a limited company under the title of J. A. Radley (Laboratories) Ltd. This company will continue to supply analytical, technological and developmental services as before. In the last few months the laboratories have been extended and stores, pilot plant, library and other extensions have been added to give four-fold increase of floor area over 1960.

The permanent board of governors of the research institute consists of J. A. Radley, F. A. Lyne and J. S. Stanley, and seven co-opted governors.

Fumaric acid plant

A fumaric acid plant with a capacity of 5 million lb. p.a. is to be built at the Newport, Mon., factory of Monsanto Chemicals Ltd. It is scheduled to be completed next year when it will replace interim manufacturing facilities.

Fumaric acid is derived from maleic anhydride, also made at the Newport factory, where a £1-million maleic anhydride plant recently completed by the Scientific Design Co. Inc. of New York has been brought on stream.

A new joint company was recently formed by Esso Petroleum and Fisons to produce 150,000 tons p.a. of ammonia on a site adjacent to the Esso refinery at Milford Haven. Work on the erection of this new plant, which is estimated to cost about £4 million, will begin shortly. The illustration shows Fisons' factory at Stanford - le - Hope, Essex, which obtains ammonia from the adjacent Shell refinery at Shell Haven
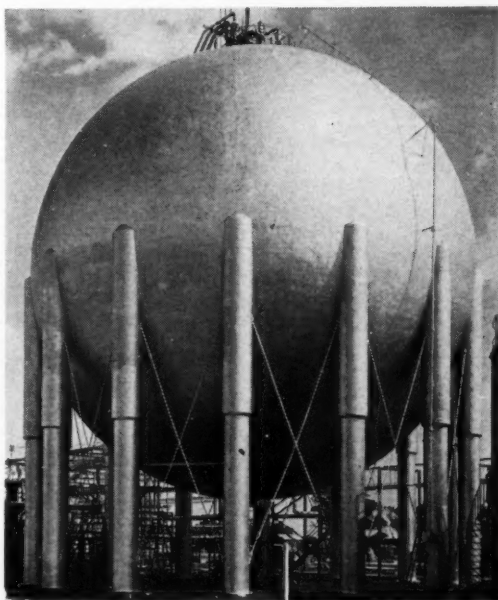
ISRAEL

Refinery expansion

The Haifa refineries, now operating at 40% capacity only, are reported to be investing I£4 million to reactivate one of the three cracking and distilling units which has been idle since the end of the British Mandate. Four petrochemical plants, which will produce carbon black, ethylene, polyethylene and DDB, are being built near the refineries at an investment of $16 million by an American, a Latin American and two Israeli groups.

CANADA

Ammonia synthesis

At the new ammonia synthesis plant which Brockville Chemicals Ltd. have recently built in Matland, Ontario, at a cost of $17 million, production of anhydrous ammonia and ammonium nitrate should commence this month. Brockville chemicals was formed last year as a subsidiary company of Songemines Ltd., which is the Canadian branch of Société General de Belgique.

SWEDEN

Petrochemical plants

The Swedish Esso company, Svenska Esso A.B., is planning jointly with other Swedish companies to erect petrochemical plants in the vicinity of Goteborg.

A steam cracking unit having a capacity of 200,000 to 300,000 tons p.a. of crude oil will first be erected. It is planned to obtain 50,000 to 75,000 tons p.a. of ethylene and later propylene and butadiene from this. Part of the ethylene will be converted to low-density polyethylene. By the end of 1963 the output of this plastic is expected to be 15,000 tons p.a.

Fluor Engineering & Construction Co. Ltd. will carry out the detailed engineering and procurement of the £7-million steam cracking plant.

SPAIN

Proposed chemical plant

A U.S. firm—W. R. Grace & Co.—awaits the Spanish Government's decision on its proposal to erect a chemical plant on the Mediterranean coast. The subsidiary company, to be known as Darex Espanola, would manufacture synthetic rubber, catalysts, plastic film and fertilisers.

UNITED STATES

Polyether plant

Allied Chemical will become the first American company to supply both principal components of urethane plastics when commercial production of polyethers begins in July at the Solvay process division's Baton Rouge, La., plant. The polyether plant's initial capacity will be 20 million lb. p.a. It will make propylene oxide-based polyethers by a new process.

Gas reforming

A Chemico high pressure-gas reform furnace operating at 250 p.s.i., designed by the Chemical Construction Corp., for the production of synthesis gas, was recently placed on stream at an ammonia plant built for the Office National Industriel de l'Azote (O.N.I.A.) in southern France.

This gas reform furnace, it is claimed, has the highest pressures yet obtained and improved heat recovery in the combined gas reform and CO_2 removal system, allowing heat to be exported to the rest of the plant.

IRELAND

Sulphuric acid plant

Irish, Belgian and Canadian interests are to build a £2-million plant near New Ross to manufacture 115,000 tons of sulphuric acid a year. Pyrites —the main raw material—will be obtained from the St. Patrick copper mines at Avoca. A large part of the plant's output of superphosphates and compound fertilisers, to be produced with the aid of imported phosphate rock and ammonia, has been scheduled for subsequent export.

UGANDA

Superphosphate plant

The Uganda Development Corporation has decided to exploit the extensive potash deposits near Tororo by erecting a superphosphates plant in Tororo, to be completed towards the end of this year. The capacity of this plant will be 25,000 tons p.a. superphosphate. Although it is not clear at present from where the sulphuric acid for this process will be bought, it is possible that a sulphuric acid plant will be built by Kilembe Mines Ltd., who have ample copper sulphide ores.

INDIA

Fertiliser plant

A fertiliser plant costing £20.7 million is to be built at Trombay by Hindustan Chemicals & Fertilisers, a state-owned company.
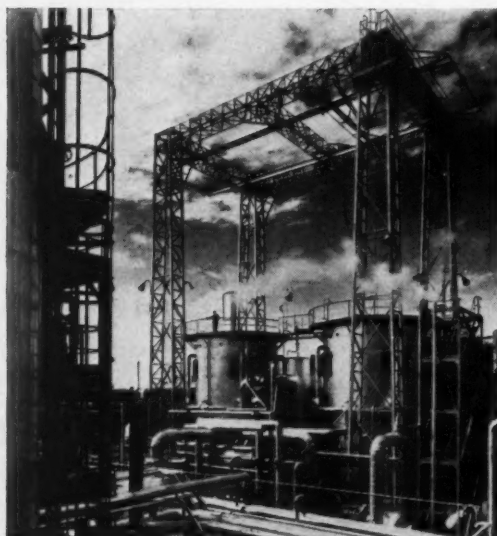
A view of the high-pressure gas reform furnace for the production of synthesis gas built for O.N.I.A., France, by Chemical Construction Corp.